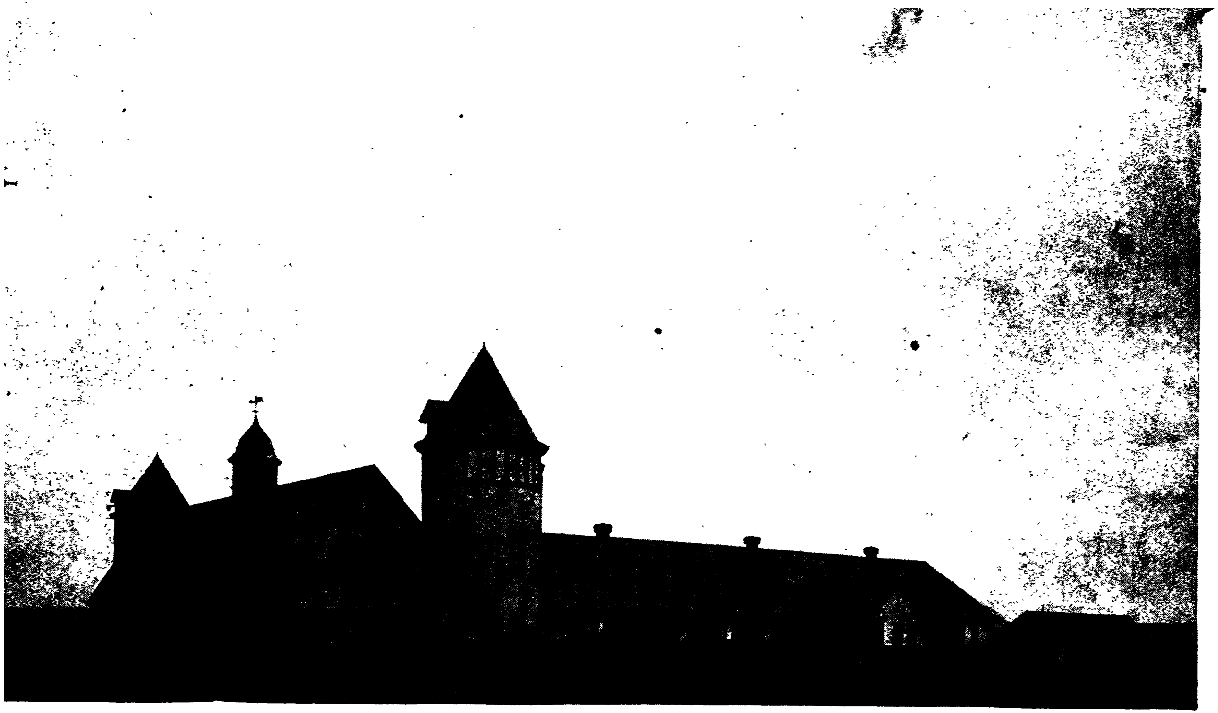
DAIRY CATTLE FEEDING AND MANAGEMENT



Frontispiece.

The Dairy Barn at The Pennsylvania State College.

DAIRY CATTLE FEEDING AND MANAGEMENT

Third Edition

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PREFACE TO THIRD EDITION

THE Second Edition of "Dairy Cattle Feeding and Management," published ten years ago, met with general favor both among practical dairymen and among teachers of dairy husbandry in agricultural colleges and secondary schools. Since its publication the science of dairying has advanced rapidly, especially in the fields of nutrition, pathology, genetics, and economics. For this reason the book has been entirely rewritten and enlarged, although the general plan of the former edition has been retained. Two entirely new lectures have been included and others have been expanded and brought up to date.

In the writing of the present edition, the latest literature on the various subdivisions of the subject has been used, and in each case where the author of any statement is known, credit is given in footnotes. In addition, a list of references for further study is included at the end of each lecture so that students who desire may pursue their studies on the various subjects. The instructor can also use these references for outside assignments.

The object of the author of this book has been to bring together in a compact and teachable way the more important findings of investigators in the field of dairy husbandry. It has not been the purpose to tabulate every experiment that has been published on the various subjects discussed, but rather to present the best information available at the present time. No doubt many worthy articles will be entirely omitted, but in a book of this size not all references can be included. The book is divided into lectures with the idea that one recitation period may be spent on each lecture. When two lectures are given per week, the complete course can be covered in eighteen weeks; or by giving three lectures per week, the course can be completed in twelve weeks. One extra period per week can be devoted to outside assignments. Suggested laboratory exercises are given in the Appendix. If less than two labora-

tory exercises per week are devoted to the course, certain of these exercises may be omitted.

Although the book has been written primarily for the student of dairy cattle feeding and management, it is believed by the author that the lectures may be used as a reference and a helpful guide by practical dairymen, herdsmen, teachers, and many others interested in the feeding, care, and management of dairy cattle. The author wishes to express his obligation to Dr. C. W. Turner for aid in preparation of the lecture on milk secretion; to Dr. E. N. Moore for aid in preparing the lecture on common diseases of dairy animals; and to Mr. L. F. Herrmann for aid in preparation of the lectures on cost accounts.

H. O. HENDERSON.

MORGANTOWN, W. VA.
January, 1938.

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DAIRY CATTLE FEEDING AND MANAGEMENT

LECTURE I

THE RELATION OF DAIRYING TO AGRICULTURE

MORE than 80 per cent of all the farmers in the United States are interested in the feeding, care, and management of dairy cattle. There are approximately 25,000,000 dairy cows in this country producing milk for human consumption or for the manufacture of dairy products. Because of the nature of dairy products, and especially of milk, the producer and consumer are equally interested in maintaining an adequate and wholesome supply of these products. There is a daily demand for milk or some of its products by every family, throughout the year. There are no substitutes for milk. Children must have it for growth; adults require it for health; and invalids as well as old people must turn to it as a means of prolonging their lives.

Dairy husbandry, as it exists today, is of comparatively recent origin. Milk, however, has been used as food for man from the very earliest times. As far back as history records, milk and its products, especially butter and cheese, were used as articles of food. The book of Genesis contains records of their use, and excavations reveal the presence of the bones of dairy animals among very ancient remains of human life. Through all the ages dairying has held an important part in the agriculture of the various nations, but it did not begin to reach its present status until about 1850.

Nature intended the cow to produce enough milk to feed her calf, but man has developed this function to such a point that frequently today a single cow produces sufficient milk to feed many calves. As land was taken up and the herder was not permitted to move his cattle from field to field as he found new pasture necessary,

he was obliged to adopt a system of feeding that required a greater production.

The dairy cow, to be profitable, must be the producer of a large amount of milk. In order to do this she must be able to consume large quantities of feed. The average cow in the United States produces only about 4200 pounds of milk. Many cows, however, have produced many times this amount, showing that the possibilities for improvement are great.

By far the greatest proportion of milk produced in this country is from the small dairy herd. It is possible to produce milk as a

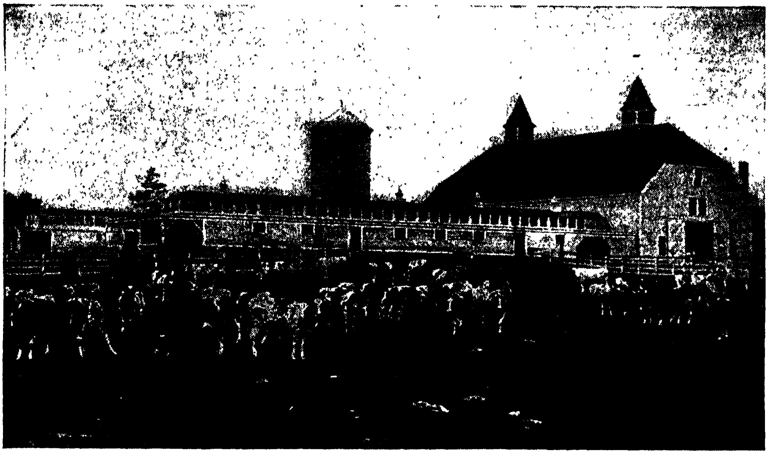

FIG. 1.—A large specialized dairy.

side line and to sell it cheaper than that produced in the specialized dairy, where all labor must be hired and where good marketable crops must be fed. In a dairy of few cows, much of the roughage, such as stover, straw, and hay, that may be discolored by rain or otherwise made unmarketable, can be used to a better advantage than by putting it on the market. Moreover, a few cows may often be milked and cared for without extra cost for labor.

Because of the competition brought about by the small dairy herds on general farms, the large specialized herds have been developed under certain definite conditions. However, with the increased demands for milk produced under exceptionally clean conditions from healthy cows, the specialized dairy has gradually taken the

place of the system of milk production as a side line, especially in those sections where milk is produced for direct consumption. Special equipment and methods are needed for producing clean, sanitary milk. Such milk is produced at a somewhat higher cost, but the consumer willingly pays for the improvement in quality.

A few other animals besides the cow have been used for the production of milk. The most common of these is the goat, though the mare, the ass, the ewe, the water buffalo, and other animals have been used in other countries. In the United States the goat is the only animal besides the cow that is used to produce milk commercially. Goats' milk is produced for infant feeding, although it is used to a limited extent for other purposes.

Extent of the Dairy Industry

Although the dairy industry in the United States developed slowly at first it has increased very rapidly within the past eighty years. Table I shows the amount of milk produced and its utilization, as given by the United States Department of Agriculture.

TABLE I

Milk Production and Utilization *

Purpose for Which Used	Whole Milk Used, 1000 lb.	Percentage of Total Milk	Amount of Product Produced, 1000 lb.	Amount Consumed per Capita
Household purposes	47,571,764	46.75	....	43.7 gal.
Creamery butter	35,588,868	34.97	1,694,708	13.4 lb.
Cheese (all kinds)	5,790,130	5.69	579,013	4.6 lb.
Evaporated and condensed milk	4,197,642	4.12	1,908,019	15.1 lb.
Ice cream	2,742,150	2.69	182,812†	1.5 gal.
Fed to calves	2,659,000	2.61	....	....
Dry milk and cream	128,187	0.13	15,934	....
Malted milk	35,289	0.03	13,569	....
Wasted (estimated)	3,052,980	3.00	....	....
Total milk used	101,766,000	100.00	....	805 lb. 93.6 gal.

* Taken from Agricultural Statistics, 1936. † Gal.

TABLE II

MILK COWS AND HEIFERS TWO YEARS OLD AND OVER, THEIR AVERAGE PRODUCTION, TOTAL PRODUCTION, AND PERCENTAGE OF GROSS INCOME FROM MILK *

Rank	State	Number of Cows, thousands	Milk Production per Cow, pounds	Total Production of Milk, million pounds	Percentage of Gross Farm Income from Milk
1	Wisconsin	2090	5100	10,659	49.39
2	Minnesota	1740	4300	7,482	30.50
3	Iowa	1506	4100	6,175	17.02
4	Texas	1385	2800	3,878	13.10
5	New York	1305	5351	6,983	46.19
6	Illinois	1175	4380	5,146	22.66
7	Missouri	1047	3280	3,434	17.63
8	Ohio	1012	4300	4,352	25.81
9	Kansas	892	3630	3,238	15.64
10	Pennsylvania	880	4950	4,356	41.65
11	Michigan	875	4800	4,200	31.73
12	Indiana	790	3820	3,018	19.67
13	Oklahoma	775	2950	2,286	19.51
14	Nebraska	750	3880	2,910	13.99
15	California	638	6450	4,115	14.06
16	North Dakota	620	3175	1,968	25.63
17	South Dakota	588	2900	1,705	21.18
18	Kentucky	583	3220	1,877	17.38
19	Tennessee	560	2930	1,641	13.84
20	Mississippi	545	2300	1,254	10.91
21	Arkansas	470	2480	1,166	13.00
22	Alabama	431	2700	1,164	13.79
23	Virginia	400	3180	1,272	16.08
24	Georgia	375	2820	1,058	11.32
25	North Carolina	361	3430	1,238	9.28
26	Washington	321	5700	1,830	18.87
27	Louisiana	290	1900	551	12.53
28	Colorado	278	3790	1,054	14.12
29	Vermont	272	4720	1,284	62.22
30	Oregon	270	5050	1,364	22.32
31	West Virginia	242	3250	786	29.83
32	Idaho	200	5020	1,004	14.85
33	Montana	198	3750	742	10.95
34	Maryland	183	4120	754	29.18
35	South Carolina	170	3250	552	11.46
36	Maine	146	4420	645	31.38
37	Massachusetts	129	5525	713	37.71
38	New Jersey	127	5980	759	31.14
39	Connecticut	116	5360	622	47.25
40	Florida	109	2650	289	9.96
41	Utah	106	4890	528	18.79
42	New Hampshire	81	4700	381	43.77
43	Wyoming	72	3680	265	9.54
44	New Mexico	69	2960	204	10.09
45	Arizona	43	4900	211	11.87
46	Delaware	33	3780	125	17.92
47	Rhode Island	22	6050	133	49.35
48	Nevada	21	4550	96	16.46
	Total	25,291	4012	101,467	21.22

* U.S.D.A. Census Reports.

The number of cows and heifers two years old and over kept for milk is a little over 25,000,000. The number of such cows in the various states, together with their production, and the percentage of the gross farm income that is received from the dairy cow, are given in Table II, arranged according to the number of dairy cattle within the state.

Although the United States has more dairy cattle than any of the European countries, the number is not so large in proportion to the area as in some European countries, nor is the production of the cows as high. The dairy industry in the United States is today, however, the largest and most profitable branch of the farm business. About one-quarter of the total value of farm production comes directly or indirectly from the dairy cow. The growth of the dairy industry during the past decade has been very great. This has been due largely to the fact that the consumption of dairy products has increased about 50 per cent during that time. This increase in consumption has been brought about to a very large extent by a better understanding of the high dietary value of milk.

The increased efficiency in the production of milk has also been remarkable. The average milk production of the cows in the United States has increased in the past 25 years over 1000 pounds per cow. There has been a steady increase in the number of cows and in total production during the period from 1840 to the present. Production per cow has also increased so that there has been a gradual decrease in the number of cows per 1000 population. This is shown by Table III.

This increase in production has been brought about by the adoption of more efficient methods. Dairymen understand the problem of feeding better than they did formerly. They are also culling their herds more closely—raising the heifer calves from their best cows and disposing of the others, and selling off all cows that do not show a profitable production.

Reasons for and against Dairy Farming

There are several reasons why dairy farming has reached its present place in the agriculture of our country. In the first place, milk is an excellent food and cannot be replaced in the diet without considerable difficulty; in the second place, dairy cows produce food

TABLE III

PRODUCTION STATISTICS, 1840–1935 *

Year	Milk Cows on Farms, thousands	Average Milk per Cow, pounds	Total Milk Produced, million pounds	Farm Cows per 1000 People
1840	4,837	....	......	287
1850	6,385	....	......	278
1860	8,586	....	......	276
1870	8,935	....	......	234
1880	12,443	....	......	251
1890	16,512	....	......	264
1900	17,136	....	......	237
1910	20,625	2902	59,854	225
1920	19,675	3964	77,992	203
1930	22,443	4510	99,705	205
1935	24,407	4169	101,756	208

* Adapted from U.S.D.A. Reports.

more economically than any other kind of livestock; and in the third place, with dairy farming the fertility of the soil can be maintained more readily than with any other type of agriculture. Furthermore, dairying is a stable form of agriculture and gives quick and regular returns.

In pointing out the disadvantages of dairying it may be said that good labor is hard to obtain, that a large amount of capital is needed to start a specialized dairy business, and that much risk is involved.

Milk as a Food.—That milk is an excellent food, especially for growing children and invalids, has long been recognized, but the reason for this was not fully appreciated until recently. It has been known for a long time that the solids of milk are present in just the right proportion to produce the best results, and that milk is digestible and palatable. Recently, however, it has been found that there is more to be considered in the diet than these essentials. We know now that not all the proteins are of equal value, as some of them do not contain all the important amino acids which the body requires. The proteins of milk, however, are very complete, and when milk is fed with the cereals it supplements their proteins in such a way that good results are obtained.

The diet must contain, besides these, two other factors, namely, sufficient mineral matter and the vitamins. Milk contains all the important minerals needed in the body, with the possible exception of iron and iodine. It is particularly rich in calcium, which is the element most likely to be deficient in the ordinary diet. A deficiency of minerals causes poor teeth and other bodily ailments.

Milk also contains the six important vitamins which are necessary for the growth of the young and the well-being of the adult. No other food, except green leaves, contains all the vitamins, and man must therefore depend largely upon milk for his supply of these important elements.

For these reasons, milk is one of the most important food substances and must be supplied in liberal amounts. It has been said that no nation that was not a great consumer of milk has ever become a great world power, and also that our country cannot maintain its present position as a world power without the continued use of milk.

Dairy Cows as Efficient Producers of Human Food.—Of the common domestic animals, the cow is the most economical producer of human food. A comparison of the dairy cow with other animals, as to efficiency in the production of human food, is given in Table IV.

TABLE IV

HUMAN FOOD PRODUCED BY ANIMALS FROM 100 POUNDS OF DIGESTIBLE MATTER CONSUMED *

Animal	Marketable Product, pounds	Edible Solids, pounds
Cow (milk)	139.0	18.0
Pig (dressed)	25.0	15.6
Cow (cheese)	14.8	9.4
Calf (dressed)	36.5	8.1
Cow (butter)	6.4	5.4
Poultry (eggs)	19.6	5.1
Poultry (dressed)	15.6	4.2
Lamb (dressed)	9.6	3.2
Steer (dressed)	8.3	2.8
Sheep (dressed)	7.0	2.6

* From Feeding of Farm Animals, Jordan.

From 100 pounds of digestible matter consumed, the cow yields 139 pounds of milk, 18 pounds of which is edible solids, practically all digestible. On the same basis the pig returns 25 pounds of marketable product of which 15.6 pounds is edible. The pig and the hen are the greatest competitors of the dairy cow in the production of human food. Both, however, require a different kind of food from the dairy cow, which consumes vast quantities of roughage, such as hay, straw, stover, and other rough feed that would often go to waste otherwise. The pig and the hen must have an abundant supply of grain and cannot utilize large quantities of roughage.

Both the sheep and the steer, on the other hand, are adapted to utilize roughage; but the dairy cow returns about six times as much edible solids in her milk, for each 100 pounds of digestible nutrients in the feed consumed, as the sheep or the steer yield in their carcasses, and the cow still remains to continue production for two to six years longer. This fact accounts, no doubt, for the prominent place held by the dairy cow in intensive farming, and by the steer in extensive farming. It also accounts for the decrease in the number of beef cattle in the country as the population increases and the size of the farm decreases, and for the accompanying increase in the number of dairy cattle. The dairy cow fits into an intensive system, and is the chief producer from the very high-priced land of Holland and Denmark.

Relation of Dairying to Soil Fertility.—Dairy farming, perhaps more than any other system of farming, makes it possible to conserve the fertility of the land and even to build up the soil. This is especially true in intensive dairying, when some of the grains are purchased, and even more so when butter is sold off the farm. Such feeds as wheat bran, linseed meal, and cottonseed meal, which are the ones commonly purchased for dairy cows, are rich not only in nitrogen but also in phosphoric acid and potash. The amounts of the fertilizing constituents contained in a few of the common feed stuffs, together with their value per ton, based on the normal prices of the fertilizer constituents, are shown in Table V.

Table V shows that whenever a ton of hay or straw is sold off the farm it takes with it a certain amount of soil fertility which

TABLE V

FERTILIZING CONSTITUENTS OF 1000 POUNDS OF MATERIAL AND ITS VALUE PER TON

Feeding Stuff	Feeding Constituents in 1000 Lb.			
	Nitrogen, lb.	Phosphoric Acid, lb.	Potash, lb.	Value per Ton *
Alfalfa	23.8	5.4	22.3	$12.28
Clover hay	20.5	3.9	16.3	10.22
Timothy hay	9.9	3.1	13.6	5.58
Corn silage	3.4	1.6	4.4	1.96
Corn meal	14.9	6.1	3.7	6.94
Gluten feed	40.6	6.2	2.3	17.08
Wheat bran	25.1	29.3	16.1	14.58
Wheat middlings	27.7	21.1	11.8	14.36
Cottonseed meal	63.7	26.6	18.0	29.94
Brewers' grains (dried)	42.4	9.9	0.9	18.04
Oats	19.8	8.1	5.6	9.28
Linseed meal	54.2	17.0	12.7	24.64

* Nitrogen figured at 20 cents per pound and phosphoric acid and potash at 5 cents per pound

must be replaced in some manner if the farm is to maintain its fertility. Where dairy farming is practiced, usually all the hay, straw, and grain are fed on the farm, and very often large amounts of high-protein feeds, such as cottonseed meal and linseed meal, are purchased for supplementary feeds. These add very materially to the fertility of the soil. When these and the home-grown feeds are fed to the dairy cow, about 70 per cent of fertilizer value can be restored to the farm in the form of manure. The selling of milk, and more especially of butter or cream, does not take very much fertility from the soil.

In general, farms on which no livestock is kept are not maintaining their soil fertility. It is not necessary to keep livestock in order to maintain fertility, but livestock farms are almost universally in a higher state of production than other farms. This is accounted for by the fact that manure is a by-product that cannot usually be marketed, whereas the maintenance of fertility by commercial fertilizers requires a direct cash outlay.

Sure and Regular Returns.—Of all the farm occupations, that of dairying gives the surest and most regular returns. In the raising of beef or of grain, the return comes but a few times during the year, but with dairying the returns are steady throughout the year. There is always a market for dairy products. It is true that the returns at times may not be as great as they are with other forms of livestock, but on the whole they vary less than with any other agricultural product.

With the development of good roads and with increased transportation facilities, dairying is spreading to all parts of the country.

FIG. 2.—A dairy barn with attractive surroundings.

Formerly, most of the butter was made in the Eastern States; but with improved shipping facilities, and because the cost of production in the Middle West is low enough to make up for the greater cost of transportation from the Middle West to the East, there has been a great decrease in the amount of butter made in the East. The same is true of milk, except that the generalization applies only to somewhat shorter distances. The dairymen within a few miles of a city are now obliged to compete with dairies 400 or 500 miles away, and even farther. This is due largely to the use of improved refrigerator and tank cars. Centralizers are buying cream from territory many miles from the place of manufacture. Today, as a

result of these developments, there is a market for all the milk produced.

The Labor Situation.—The problem of labor on the dairy farm is a perplexing one. In some sections it is not difficult to secure men who are competent to do dairy work. In other sections, however, labor is scarce and therefore hard to obtain. The long hours required and the low wages paid by dairy farmers, as compared with the prices paid in other industries in the community, sometimes result in discontent.

The labor problem is further complicated by the fact that more intelligent men are required in dairying than in many other lines of work. This limitation restricts the number of men available for the dairy, and also requires that they be selected from a class who are paid more than ordinary laborers. Many states have passed workmen's compensation acts, but few of them have extended their scope to include men employed on dairy farms. This fact also may have a slight tendency to cause men to seek employment elsewhere.

These disadvantages are well known; but there are other factors which tend to make the labor on a dairy farm more stable. Whereas in most other forms of agriculture, and even in the industries, employment is very uncertain, on the dairy farm it is certain and continues throughout the entire year. Even though the wages are not so high as in some other occupations, nevertheless they are paid regularly, and at the end of the year may amount to more than in many other forms of work. It is true that the hours are usually long, but many dairymen are now regulating their work so that their help have as much time off as other farm hands. This is necessary if the men are to be kept contented. Much of the monotony of dairying has been taken away by labor-saving devices, such as the milking machine. If attention is paid to the matter of labor, many of the disadvantages will disappear.

Capitalization and Risk.—A farmer cannot establish a specialized dairy unless he has a large amount of capital. From the standpoint of capital, good dairy cows and good dairy equipment are expensive. They also require a large outlay of money for feed and labor. This should be compensated for by an increase in the price of the special product. However, it is not often wise for a beginner to go into the dairy business without previous experience.

It is usually better to grow into it, as one can do gradually and with a minimum amount of outlay.

A man with a herd is also confronted with risks because of disease and sickness which may develop among the animals. These things must be considered when going into the dairy business.

Unprofitable Dairies

Many of the dairy herds in this country are unprofitable. This difficulty will be largely remedied by more efficient methods of production. Careful records of cost show that many dairies are running at a loss. Any one of the following reasons may be given to explain why dairymen who operate at a loss continue in the business:

1. On account of changed conditions some dairymen are producing milk either at no profit or at a loss. An improved method of shipping milk may be a factor in such a case. A dairyman who lives near a city is able to sell his straw, stover, and other feeds at a higher price, and perhaps his labor is also high priced. With improved facilities of transportation he is obliged to compete with a farmer who occupies cheaper land and who places a low value on his coarse feeds.

2. Certain dairymen are satisfied to produce milk at actual cost in order to get some return for labor that they could not use without the dairy. To illustrate, let us assume that one of two farmers, each with 160 acres of equally good land, has 10 cows, and that the other has none; that the farmer with 10 cows sells his milk at exactly the price that careful and accurate records show it to cost. Figuring roughly that labor is charged at $30 per cow yearly, the farmer with 10 cows will have $300 more than his neighbor at the end of the year, for he will spend no more for his labor. In the summer his children are at home to do the milking, and during the winter it can be done by the farmer himself. He is, therefore, at the end of the year, $300 better off than his neighbor. Some consider that this $300 is not saved, that it is merely pay for the work done; others, that it has nothing to do with the actual cost of milk. It is, nevertheless, one reason why some dairy farmers are apparently more prosperous than farmers on similar farms without cows.

3. Some dairymen have land that cannot be used for anything except pasture, or have stover or inferior hay and other feeds that can be utilized for milk production but cannot be marketed.

4. There are those who found the milk business profitable when feed, labor, and other requirements were cheaper. Although the price for their product may not have advanced in the same proportion as its cost, they continue in the hope of eventually getting a higher price for the milk.

5. With some farmers a few cows fit in well with the general farm scheme. To this class belong those who have a little pasture, those who want a certain quantity of manure for a particular crop, and those who want a certain small cash income throughout the year. It is the farmers with small herds, more than any others, who produce the bulk of the milk of this country and keep the price low.

6. There are a certain number of wealthy men who do not care whether they make any money or not. They keep cows for a hobby or to furnish milk to some establishment where good milk is desired regardless of cost.

The above reasons are not given to justify low prices of milk, but rather to explain why some are producing milk although, when all actual costs are counted, the business does not show a profit.

Pure-bred Dairy Cattle

For those who have sufficient capital and know the methods of breeding, the raising of pure-bred dairy cattle offers a special opportunity. Most of the dairy cattle in this country are grade animals. As dairymen are constantly seeking to improve the production of this class of cattle, higher-producing pure-bred animals are needed in order to furnish the necessary breeding stock. Perhaps the greatest development of the industry, as far as the animals themselves are concerned, will be brought about by the use, in the grade herds, of bulls that will increase the production of those herds. The value of a good bull can hardly be overestimated, and the producers of milk and dairy cattle are rapidly learning this. They are willing to pay high prices for good breeding stock. There has always been a demand for good pure-bred animals, and this de-

mand will probably always continue. Therefore, the dairyman who can produce not only good milk but also high-class livestock, and who can properly feed, show, and market the animals, can establish an especially desirable business. The raising of pure-bred cattle is a separate business, distinct from that of producing milk.

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LECTURE II

THE COMPONENTS OF PLANTS AND ANIMALS

ELEMENTS OF ANIMALS AND FEEDS

OF THE many chemical elements now known, only eighteen are important so far as plant and animal life is concerned. Six of these elements, namely, oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus, make up 98.5 per cent of the plant or animal; the others occur in minute amounts varying from mere traces up to 0.5 per cent. These in order of the amount found in the animal body are potassium, sulphur, sodium, chlorine, magnesium, iron, iodine, fluorine, silicon, zinc, nickel, cobalt, copper, manganese, and arsenic. Some of these, though found in very minute quantities, are nevertheless necessary for life and well-being. Others do not seem to have any known function.

COMPOUNDS

The elements named above combine to form a great many different compounds. These compounds can be divided into five great classes, as follows: water; ash; crude protein; carbohydrates; and fat, which is also called ether extract. Frequently the carbohydrates are further divided by the chemist into nitrogen-free extract and crude fiber. The following diagram will show how these compounds of the plant are divided during analyses. The water and ash are incombustible; the remaining compounds are combustible.

All feeding stuffs consist of

Water — Dry matter

Dry matter: Ash — Organic matter

Organic matter: Protein — Carbohydrates — Fat or ether extract

Carbohydrates: Nitrogen-free extract — Fiber

It is necessary to study these compounds before we can understand how they can be used by the animal body.

Water

Water is a very necessary compound of plants and animals. The bodies of animals are 70 to 90 per cent water. Water has several very important functions in the animal body. It gives elasticity and rigidity to the supportive tissue of the animal, helps to dissolve the food, acts as a carrier of food and waste, helps to maintain the osmotic pressure of the body, and prevents extensive changes of temperature. It also has the power to dissociate into hydrogen ions and hydroxyl ions with the result that it readily unites with many types of compounds. Any interference with the normal amount of water, in either plants or animals, produces disastrous results. Water, therefore, should always be supplied to livestock in large amounts.

Dry Matter

If a substance is heated to a temperature at or above that of boiling water until it ceases to lose weight, the remaining residue is known as dry matter. The loss of weight represents the moisture or water. A small amount of moisture, however, is still held in the dry matter. Dry matter is divided into organic matter and ash or inorganic matter.

Ash or Mineral Matter

When dry matter is burnt the organic matter can be burnt out, leaving what is known as ash or mineral matter. There is considerable ash in all the common feeding stuffs. In the animal the dry matter of the bones consists largely of ash, while the dry matter of the rest of the body contains, on the average, about 7.1 per cent of ash.[1] The analysis, however, does not tell how the inorganic matter is distributed in the body. The important minerals which are most likely to be lacking in the animal body are calcium, potassium, sodium, iron, phosphorus, chlorine, fluorine, iodine, sulphur, copper,

[1] The Nutrition of Farm Animals, Armsby.

and magnesium. Silicon, manganese, cobalt, nickel, and zinc are usually present in sufficient amounts.

The functions of the minerals in the animal body are numerous. They furnish material for the formation of new tissues, especially that of the skeleton, and of the mineral part of the milk. Minerals are important in young, growing animals, and for mature ones giving milk.

The minerals help to maintain the osmotic pressure. The cells of the various body tissues draw their nourishment from the lymph, from which they are separated by cell walls. These walls partake of the nature of a semi-permeable membrane. In order to maintain normal conditions in the protoplasm of the cells, the osmotic pressure of the lymph, and therefore that of the blood from which it is derived, must be maintained approximately constant. The constant osmotic pressure is due largely to minerals contained in solution.

The minerals help to maintain the proper ionic concentration in the body. Certain important reactions in the body will not take place unless the proper ionic concentration is maintained. Ptyalin, for example, is very sensitive to acid, but pepsin is most active when the reaction is slightly acid. The different minerals dissociate and yield the desired ionic concentration.

The minerals help to maintain the neutrality of the body. The body katabolism is continually producing acids, especially carbonic, phosphoric, and sulphuric, which tend to increase the acidity of the blood. These are in part neutralized by the ammonia produced in the katabolism of the protein, and in part by the salts in the blood serum, especially the sodium phosphate and bicarbonate, which play an important part in maintaining its neutrality.

The minerals aid in respiration. Iron is an essential part of the hemoglobin by means of which the oxygen is distributed through the body. Iodine also is an essential ingredient of thyroxine, a hormone secreted by the thyroid gland.

The minerals are also necessary in putting certain materials into solution. Certain proteins, for example, are soluble only in dilute salt solutions. Some minerals also aid in digestion, especially of the fats and protein, and others are useful in protein and carbohydrate metabolism. They have the power to dissociate with the for-

mation of ions which possess the power of conducting electric currents and are in this way very closely related to the chemistry of life.

Organic Matter

The chemist determines the organic matter by taking the difference between the dry matter and the ash. Organic matter is divided into three groups, namely, protein, fat, and carbohydrates.

Protein.—The crude protein of feeding stuffs is not determined directly by the chemist. The usual method of analysis is to determine the amount of nitrogen, and then to multiply this amount by the factor necessary for the particular feed. The factor most commonly used is 6.25.

Classification of Proteins.—The proteins have been classified, not according to their nutritive properties, but according to certain characteristic chemical properties, particularly that of solubility. The classification is as follows:

A. SIMPLE PROTEINS.—These are naturally occurring proteins, which, on being treated with enzymes or acids, break up only into amino acids or their derivatives.

1. *Albumins.*—These are soluble in pure water and coagulable by heat. Egg albumin, lactalbumin, and serum albumin are the most important ones, but others are found in small amounts in some of the common grains and legume seeds.
2. *Globulins.*—These are insoluble in pure water, but soluble in neutral salt solutions. Globulins are found in blood, in milk, and in many of the seeds.
3. *Glutelins.*—These are insoluble in pure water and neutral salt solutions; are soluble in dilute acids or alkalies. They are characteristic of the cereals. Combined with a prolamine, they form the gluten.
4. *Prolamines.*—These are soluble in 70 per cent alcohol. They are found especially in the seed of the cereals. Zein in corn, gliaden in wheat, and hordein in barley are examples.
5. *Albuminoids.*—These are insoluble in all neutral solvents, but are soluble in strong acids or alkalies, which decompose them. They are found in animals only. Collagen, found in connective tissue, and keratin, found in epidermal tissue, such as hair, horn, and hoof, are examples.
6. *Histones.*—These are soluble in water but insoluble in very dilute ammonia. They are found only in animals. The globin of hemoglobin in the blood is a histone.

7. *Protamines.*—These are soluble in water, and not coagulable by heat. They are also found in animals. They have the smallest number of amino acids in their molecule of any class of proteins.

B. Conjugated Proteins.—These are compounds of simple proteins with some other non-protein groups. The non-protein groups are usually acid in reaction.

1. *Nucleoproteins.*—These are proteins combined with nucleic acid and are especially characteristic of the nucleus of the vegetable or animal cell.
2. *Glycoproteins.*—These are proteins combined with substances containing a carbohydrate group other than nucleic acid. The mucins and mucoids are the most important.
3. *Phosphoproteins.*—These are proteins combined with some phosphorus-containing substance. Casein in milk and vitellin in egg yolk are important.
4. *Chromoproteins.*—These are conjugated proteins in which the additional groups are colored. The most common is hemoglobin which is a combination of globin and hematin and gives the red color to blood.
5. *Lecithoproteins.*—These are proteins combined with lecithin.

C. Derived Proteins.—This group is artificial, but includes all those decomposition products of the simple proteins which are produced by the action of enzymes or other agencies.

1. *Primary protein derivatives.*—These include proteans, metaproteins, and coagulated proteins. They are derivatives of proteins in which the proteins have been broken up slightly.
2. *Secondary protein derivatives.*—These include proteoses, peptones, and peptids, each simpler than the preceding one. They are obtained by the breaking up of the protein molecule.

Composition of Proteins.—All proteins contain carbon, hydrogen, oxygen, and nitrogen; many contain sulphur, and a few contain phosphorus. The protein molecule is very complex, and there are very few proteins of which the exact formula is known. That of hemoglobin has been given as $C_{758}H_{1203}O_{218}N_{195}S_2Fe$.

Structure of Proteins.—When simple proteins are broken down they yield amino acids. This indicates that proteins are made up of amino acids linked together. Approximately twenty-two different amino acids have been isolated. The number of amino acids contained in a protein molecule varies in different proteins. No two proteins are alike in this regard. Some proteins contain none of the more important amino acids. This fact is very important in

the study of nutrition, as it is thought that the animal cannot make these amino acids, and many of them are essential to proper nutrition.

Function of Proteins.—The function of the protein in the animal body is to supply the animal with the living tissue necessary for the replacement of all worn-out material, and to supply the protein content of the milk. Protein can also be used as a source of energy.

Non-protein Nitrogen-containing Substances.—Feeding stuffs contain a great variety of nitrogen-containing substances which are not proteins but have a very much less complex molecular structure. The most important of these compounds are amides, amines, and amino acids. Plants build up proteins through these compounds; therefore they are found in more abundance in young growing plants. Animals use amino acids to build up proteins within their bodies; when animals eat young plants, therefore, they obtain these compounds in a more or less predigested state. Armsby [1] at first thought that these compounds could not be used by animals, so he originated the term "digestible true protein," by which he meant simply the digestible crude protein minus these non-protein nitrogen-containing substances. It is agreed now, however, that these can be used as food in the animal body.

Carbohydrates.—The carbohydrates of plants are one of the most important parts of the feeding stuffs. They are found only in small amounts in animals but are especially characteristic of plants. The carbohydrates of feeding stuffs are divided into fiber and nitrogen-free extract. The fiber is the woody portion of the feeding stuff and is determined by boiling a sample in weak acid and alkali and washing out the dissolved matter. It is less digestible than the other nutriments of feeding stuffs. The nitrogen-free extract is determined by the difference and not by direct analysis. The total dry matter minus the sum of the protein, ash, fat, and fiber gives the nitrogen-free extract. It has a high nutritive value.

Composition of Carbohydrates.—The term carbohydrates means simply a compound composed of carbon, and hydrogen and oxygen in the proportion in which they exist in water. The more important carbohydrates in nutrition are as follows:

[1] U.S.D.A. An. Ind. Bul. 139.

1. *The monosaccharides, or simple sugars,* $C_6H_{12}O_6$.—In this group glucose, levulose, and galactose are the most important. Of these, glucose is the most common. It is not commonly found in the feed, but is the sugar of the body. Most carbohydrates, before they can be utilized by the body, are converted into glucose.
2. *The disaccharides, or compound sugars,* $C_{12}H_{22}O_{11}$.—In this group, sucrose, maltose, and lactose are the most important. They are compounds of two molecules of the simple sugars, with the elimination of one molecule of water, $C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$. Sucrose, also known as cane sugar, is the best known. It is the sugar of the beet and the cane, and is made from one molecule of glucose and one of levulose. Maltose, or malt sugar, is formed by the union of two molecules of glucose; lactose, the sugar of milk, is formed by the union of one molecule of glucose with one of galactose.
3. *The polysaccharides* $(C_6H_{10}O_5)_x$.—Several compounds belong to this group, but the most important in nutrition are the starches, glycogen, and cellulose. They are compounds of many molecules of the simple sugars. The starches are the reserve carbohydrates of the plant and are very abundant, especially in seeds, fruits, and roots. Glycogen is the storage carbohydrate of the body and is not found in plants. Cellulose is even more complex than the starches and goes to make up the woody parts of the plant. As plants mature, the cellulose combines with other substances, especially lignin, and forms compounds even more insoluble.
4. *Pentosans* $(C_5H_8O_4)_x$.—The pentosans are found in large amounts in animal feeds. They are the result of the union of a large number of molecules of pentose, $C_5H_{10}O_5$, in the same way as starch is formed from the union of many molecules of glucose. They are found in the largest amounts in the woody portion of plants. They are very abundant in many of the common feeds. The straws contain from 23 to 30 per cent; corn contains 5.9 per cent; and cottonseed meal, 7 per cent.

Properties of Carbohydrates.—Carbohydrates have three important properties in nutrition. They are unstable, easily oxidized, and easily reduced. All carbohydrates are very unstable in the presence of living protoplasm and can be easily broken down or changed into other sugars. They are readily oxidized, heat being given off during the oxidation (exothermic). In this manner they can be used as fuel in the body. They are also easily reduced and form products which can be readily turned into fat. In this way they can store up heat (endothermic).

Function of Carbohydrates.—The carbohydrates are the energy givers of the body. They are not stored in the body in large

amounts as carbohydrates, but can be changed into fat, the form in which energy is largely stored.

Fats.—Fats are not as important in nutrition as either carbohydrates or proteins, but they do play some part and are made and stored in large quantities by farm animals. The chemist determines the fat of feeding stuff by treating a sample of feed with ether, which dissolves the fat and related substances. This is called ether extract by the chemist, since it really contains other substances besides the fats.

Structure of Fats.—Fats are formed by a union of compounds, known as fatty acids and glycerol. They contain the same elements as carbohydrates, but their proportion of oxygen is much less, and that of carbon and hydrogen much greater. The principal saturated acids contained in the animal fats are palmitic acid, $C_{15}H_{31}COOH$; stearic acid, $C_{17}H_{35}COOH$; and arachidic acid, $C_{19}H_{39}COOH$. Others occur in small amounts. In butterfat a large number of the fats in the lower series are present, such as butyric, C_3H_7COOH.

The unsaturated acids differ from the saturated acids in that they contain two or more carbon atoms united by two bonds. As a result, the unsaturated acids contain less hydrogen than the saturated ones. The most important one in animal fat is oleic acid, $C_{17}H_{33}COOH$. Linolenic acid, $C_{17}H_{29}COOH$, found in linseed oil, and linolic acid, $C_{17}H_{31}COOH$, found in cottonseed oil, are also unsaturated.

Characteristic Properties.—Fat can be changed into fatty acids and glycerol, and vice versa. The one is a process of hydrolysis; the other, of condensation. This is a very important reaction in nutrition. It is isothermic and so does not require energy:

$$\begin{array}{l} CH_2OH \\ | \\ CHOH + 3C_3H_7COOH \\ | \\ CH_2OH \end{array} \leftrightarrow \begin{array}{l} CH_2OOCC_3H_7 \\ | \\ CHOOCC_3H_7 + 3H_2O \\ | \\ CH_2OOCC_3H_7 \end{array}$$

Fats are soluble in ether, in oils, in oily materials, and in oleic acid. They also emulsify very easily. These properties are of great importance in nutrition.

Functions of Fats.—The fats are used in the animal body as a source of fuel. They are a concentrated form of fuel containing

much more energy per unit than any of the other nutrients. Since this is true, they are well adapted for the storage of reserve energy in the body, for which function they are used. They also have, to a limited degree, certain structural functions.

REFERENCES FOR FURTHER STUDY

1. The Nutrition of Farm Animals, Armsby, Chapter I.
2. Feeds and Feeding, 20th Ed., Morrison, Chapter II.
3. Agricultural Biochemistry, Dutcher and Haley, Chapters II to V.
4. Manual of Veterinary Physiology, Smith.
5. Physiological Chemistry, Mathews.
6. Text Book of Physiology, Howell.
7. The Mineral Elements in Animal Nutrition, Forbes, Ohio Exp. Sta. Bul. 201.

LECTURE III

THE WORK OF DIGESTION

THE animal body secures all the nutrients for its growth from *solutions of the food much in the same way that plants secure all* the nutrients for their growth from water solutions in the soil. The process of preparing the food ingredients for passage into the blood stream is known as digestion. It is a process in which the complex molecules are broken down into simple ones so that the soluble portions can be separated from the insoluble, and the latter eliminated from the body. In this process the carbohydrates are broken down into monosaccharides, the fats into fatty acids and glycerol, and the proteins into amino acids. In every case a larger, more complex molecule is broken down into a smaller, simpler one. This change is brought about largely by the digestive enzymes. Many other reactions in the body are dependent on enzyme action.

ENZYMES

Enzymes are organic compounds of unknown chemical structure which have the power to change or break down other organic compounds without themselves being changed or broken down. No enzyme has ever been isolated. Enzymes do not in themselves cause any chemical action but are merely agents which control the rate at which chemical reactions take place. The most important reaction which they control is hydrolysis; however, some enzymes control oxidation and others control reduction.

Enzymes are sensitive to heat and can be destroyed if heated above a certain temperature. Some work best in an acid medium; others act only in an alkaline medium. Each enzyme of digestion is capable of acting only upon one kind of material; in other words, there is a specific enzyme for proteins, a specific enzyme for carbo-

hydrates, and a specific one for fats. There are four groups of digestive enzymes: namely, the amylases, which act on starch; the invertases, which act on the disaccharides; the proteases, which act on the proteins; and the lipases, which act on fats. These are secreted in fluids by numerous secreting glands which are essential parts of the organs of digestion.

Hormones

It has been found also that many of the body processes are *controlled and regulated by substances called hormones or internal* secretions, which are secreted by the endocrine glands, also called the ductless glands. These secretions are discharged directly into the blood stream or into the lymph, from which they enter the blood stream indirectly and not through a duct like some of the digestive juices. They act as chemical messengers to various parts of the body. These hormones perform important functions in digestion, metabolism, milk secretion, growth, and the development of sex, as will be seen in later lectures.

The more important glands of internal secretions are the thyroid gland, the parathyroid gland, the pituitary body, the adrenal glands, and the sex glands.

The Alimentary Canal

The alimentary canal of the ruminants, which include the dairy animals, is much more complex than that of other animals. It includes the mouth, the gullet, the four stomachs, the small intestine, and the large intestine. These together form a long, winding canal approximately 180 feet long in the average dairy animal. The dairy animal has four stomachs:

1. The rumen, or paunch.
2. The reticulum, or honeycomb.
3. The omasum, or manyplies.
4. The abomasum, or true stomach.

The first three of these may be considered as an enlargement of the gullet and should not be considered as true stomachs.

Digestion in the Mouth

The mouth is the organ of prehension, mastication, and insalivation. The animal, by means of its tongue, lips, and teeth, conveys its food to its mouth. With the teeth, also, it chews and prepares the food for swallowing. The dairy cow, while eating, chews her food only enough to moisten it and to form it into a mass of suitable size to be swallowed. The food is then held in the paunch until her hunger is satisfied; she then returns it, in the form of a "cud," to her mouth, where it is thoroughly masticated and mixed with the saliva before being reswallowed. The dairy animal can masticate on only one side of the mouth at a time. When this side becomes tired, the process is reversed and the opposite molars take on the work of mastication.

The process of mastication excites the three salivary glands, causing them to secrete a large amount of saliva which readily mixes with the food. The amount of saliva secreted in a day's time is enormous. Colin [1] estimates that a cow utilizes as much as 112 pounds of saliva a day. This amount is increased if the food is unusually dry. The saliva of some animals contains the enzyme ptyalin, which converts starch to sugar. In dairy animals, however, this enzyme is either entirely absent or is present in a very small amount. This is an advantage; otherwise the sugars formed from the starch might be further broken down in the paunch and wasted. The use of the saliva in dairy animals, therefore, is to assist mastication and swallowing, to stimulate the nerves of taste, and to assist rumination. Thus no true digestion takes place in the mouth. The food is merely prepared there for the later action of the enzymes in the digestive tract.

Colin states that the bolus, or "cud," weighs from 3 to 4 ounces and requires about 3 seconds to ascend and 1½ seconds to descend after complete mastication. The chewing of the "cud" occupies about 50 seconds. Rumination is, therefore, a slow process and occupies at least 7 hours out of the 24. If an animal is alarmed or disturbed she immediately ceases to ruminate. One of the very first signs of ill health is the suspension of rumination.

[1] A Manual of Veterinary Physiology, Smith.

After the food has been thoroughly masticated and mixed with saliva, the act of deglutition, or swallowing, takes place. This is

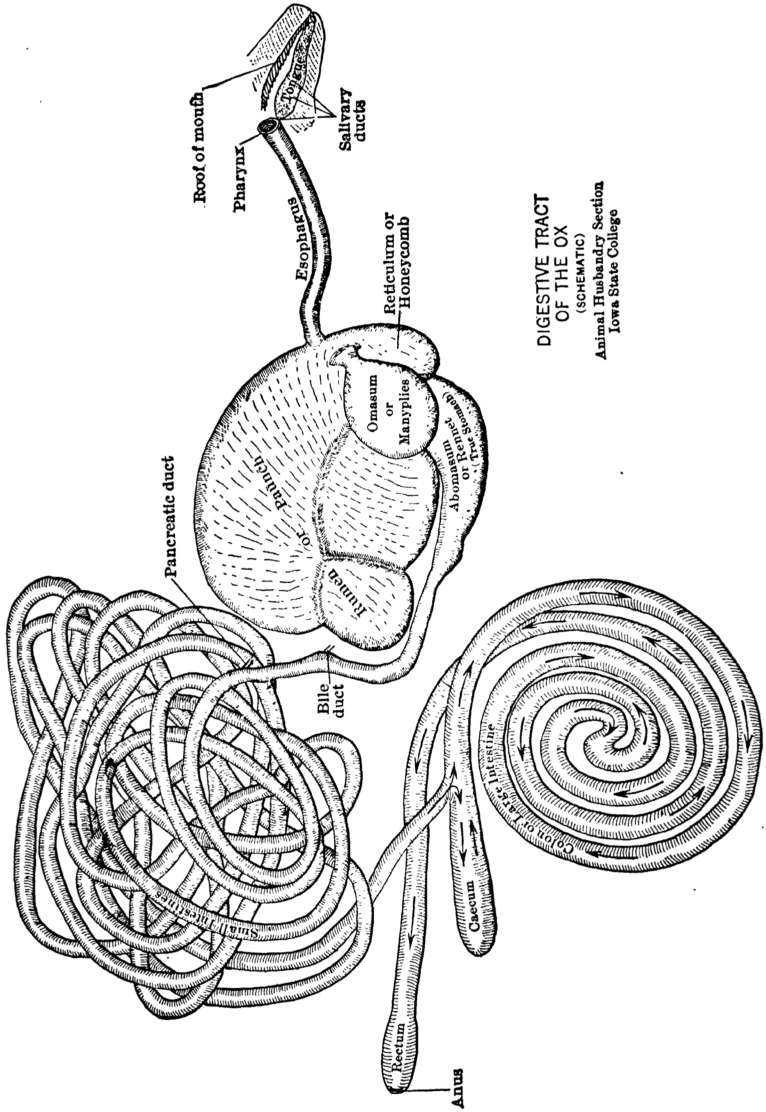

FIG. 3.—The digestive tract of the ox (schematic).

brought about by the action of the muscles of the throat and tongue, which force the food into the esophagus, or gullet, the tube-like pas-

sage extending to the stomach. The gullet of a cow is easily stretched, with the indirect result that animals are sometimes choked. Food passing into the gullet without proper mastication, such as apples swallowed in large pieces, is likely to cause choking.

Digestion in the Stomach

The Rumen.—As previously stated, mastication in the dairy cow is not completed at the time the food is taken into the body. The cow simply chews the material sufficiently to pass it through the esophagus into a reservoir called the paunch, or rumen.

The material is then held in the rumen until a convenient time for complete mastication. The rumen of the dairy cow has a very large capacity, having a breaking point of about 50 gallons. The rumen is divided into four sacs, by constrictions in the wall produced by large muscular bands. The interior of the organ is lined with a well-developed mucous membrane, covered with pointed papillae.

The food is passed back and forth in the paunch with a churning motion, fermentation taking place at the same time. When fermentation proceeds at such a rate that the blood is unable to absorb the gases formed, a case of hoven, or bloat, occurs. The bolus, or "cud," is formed when the animal desires to ruminate, and is passed back to the mouth by the combined action of the rumen and reticulum. The passage between these is known as the esophageal groove. From this groove the cud is passed into the esophagus and returned to the mouth for complete mastication.

The rumen never empties itself. Even after long periods in which no food is eaten, the rumen contains food. In young calves the first three stomachs are rudimentary and the food passes directly into the true stomach, or abomasum. The rumen has no digestive juices, and, since the saliva of the dairy cow does not contain much, if any, ptyalin, no true digestion takes place in this stomach. The contents of the rumen are generally alkaline. The fermentation in this organ enables the cow to digest large amounts of cellulose or crude fiber and pentosans which would otherwise go to waste. Certain bacteria, which form the flora of the rumen, have the power of secreting enzymes which act on the cellulose and

pentosans, thereby breaking them down with the production of heat and the formation of organic acids, particularly acetic and butyric, and such gases as methane, carbon dioxide, and hydrogen. The bacteria may also attack starch and sugar and break them down, thus causing a waste.

The Reticulum or Honeycomb.—The reticulum, or honeycomb, is much smaller than the rumen. In the dairy cow it has a breaking point of about 13 quarts. Its interior is lined like a honeycomb, hence the popular name. It is connected with the rumen and the esophagus by means of the esophageal groove. In this sac, stones, nails, and other foreign objects may frequently be found. Oftentimes nails or wires penetrate the heart from the reticulum.

The contents of the reticulum are fluid and alkaline. There is no secretion from the walls of this stomach, and as a result, it has no true digestive power. Its function has not been fully demonstrated, but it seems to assist in passing the bolus up the esophagus and to regulate the passage of the food from the rumen to the omasum, and from the rumen to the esophagus.

The Omasum, or Manyplies.—After the food has been thoroughly masticated it goes directly to the omasum. This is a peculiarly shaped organ with a breaking point of about 20 quarts. The omasum, like the reticulum and rumen, possesses no secretive powers but consists of powerful muscular leaves that squeeze the water out of the matter which it receives. Some of this water, of course, is absorbed by the organ, but most of it passes directly to the abomasum, or true stomach. The solid portion remains in the omasum to be further acted upon by the leaves. These leaves are covered with papillae which become shorter, thicker, and stiffer as the food advances. The movement of the leaves is not simultaneous, but successive, in such a way that the rasping of the food is continuous, so that the food is ground finer and finer until it enters the abomasum. When illness occurs, rumination ceases, thus cutting off the chief supply of fluid to the omasum. The content then becomes dry and often cakes, resulting in a condition in which it is practically impossible to pass anything through the animal. From the omasum the food passes directly into the abomasum.

The Abomasum, or True Stomach.—This organ, which has a breaking-point capacity of about 20 quarts, is the true digestive

stomach of the cow. The walls of this stomach secrete the gastric juices, which contain less than 0.5 per cent of hydrochloric acid, and the two enzymes, pepsin and rennin. Pepsin can act only in an acid medium; hence it is the function of the hydrochloric acid to change the alkaline condition, which the food has maintained up to this point, to an acid one. Pepsin acts on the proteins and breaks them down into simpler compounds, mainly peptones and proteoses, but does not break them down into amino acids.

Rennin is an enzyme which curdles milk, and is therefore very important in young calves that are fed milk. If it were not for the action of the rennin, the milk might pass through the digestive tract without being acted on by the other digestive enzymes.

Digestion in the stomach is sometimes spoken of as a process of chymification, since the pulpy mass of semi-liquid food which is ready to pass from the true stomach to the intestines is spoken of as the chyme. The opening of the stomach into the intestines is controlled by a sphincter muscle which in turn is controlled by the reaction of the chyme. When the chyme within the stomach becomes acid to a certain degree, this sphincter muscle relaxes and allows some of the chyme to pass through into the intestines. Mechanical stimulation may also have some effect in keeping this muscle rigid.

Digestion in the Intestines

The intestines are composed of two well-defined parts, the small and the large intestine. The small intestine is a long, folded tube into which the stomach empties. Its length in the cow is about 135 feet, and it has a capacity of about 40 quarts. The walls of the intestines are covered with very small, finger-like projections called villi, which have a lashing movement, thus helping to mix the content of the stomach. The food is carried forward in the intestines by a peristaltic movement. This is a wave of constriction followed by a wave of relaxation. The food moves very slowly, and the digestive juices have plenty of time to do their work. The upper part of the intestinal tract is specialized for secretion, and the lower part for absorption. In the intestines, the food comes into contact with three digestive juices: the pancreatic juice, the bile, and the intestinal juice.

The Pancreatic Juice.—The pancreatic juice is a clear, watery fluid with an alkaline reaction. It is secreted by the pancreas, or sweetbread, which is a slender gland lying just below the stomach. Careful experiments have shown that the pancreatic juice flows only when chyme is coming from the stomach. This chyme is acid in reaction. The acid, acting on the lining of the intestines, produces the hormone secretin, which is adsorbed into the blood, and after being carried to the pancreas, causes it to secrete the pancreatic juice. In this way the organs of digestion are made to work in harmony. The pancreatic juice contains three enzymes: trypsin, amylase, and lipase. Trypsin is a protease and, like pepsin, acts on the proteins, converting them into proteoses and peptones and breaking them up to a certain extent into amino acids, in which form the protein can be taken up by the animal body. Trypsin will not work on the protein until it is made active by coming in contact with the enzyme enterokinase, which is secreted by the intestinal walls. Amylase converts starches into maltose. In a ruminant, such as the dairy cow, it is undoubtedly used more largely than in a non-ruminant, where ptyalin has a greater effect. Lipase separates the fats into fatty acids and glycerol, thus enabling them to pass through the walls of the intestines. Some of the fatty acids unite with the alkalies in the bile and form soaps, a form in which they are soluble.

The Bile.—The bile is the thin, yellowish-brown, or greenish liquid secreted by the liver. It is alkaline in reaction and changes the reaction of the chyme as it comes from the stomach from an acid to an alkaline or neutral one. Bile is stored in the gall bladder and flows only when required. It is stimulated by a hormone in the same manner as the pancreatic juice. Bile does not contain any digestive enzymes, but it does greatly aid digestion. It is useful in emulsifying the fats, breaking them up into very small globules, and thereby greatly increasing the surface area so that the lipase can work on them more easily. It furnishes salts which may combine with fatty acids, thus forming soaps, in which form fat can be taken up by the body. It also helps to dissolve the soaps and fatty acids. If bile is excluded, the digestion of fat is reduced, and this in turn retards the digestion of carbohydrates and proteins. One of the acids which bile contains, taurocholic, accelerates the peristaltic movement

of the intestines. Colin states that the cow secretes approximately 5.7 pounds of bile in a day.

The Intestinal Juice.—The mucous membrane of the intestines is lined with glands which secrete the intestinal juice, also known as the succus entericus. This fluid contains several enzymes, the most important of which are erepsin, a proteolytic enzyme, and the invertases, namely, sucrase, maltase, and lactase. It also contains enterokinase, the principle that activates trypsin.

Erepsin acts on the proteoses and the peptones, which have been broken down from the proteins by the pepsin and trypsin, and further breaks them down to simple amino acids. It cannot act on protein that has not already been broken down to the proteoses and peptones.

Sucrase, maltase, and lactase convert the cane, malt, and milk sugar into the simple sugars. Sucrose is broken down into one molecule of glucose and one molecule of levulose; maltose, into two molecules of glucose; and lactose, into one molecule of glucose and one of galactose. These enzymes do not act upon the starch.

The Large Intestine.—When the content of the small intestine reaches the large intestine it still contains undigested food. The food remains in the large intestine a relatively long time, thus permitting the digestive processes started in the small intestine to continue, and also permitting complete adsorption of all digested food. In the large intestine the food undergoes a great deal of bacterial action. Putrefaction takes place, causing the offensive odor of the feces and often setting free large quantities of poisonous products. No digestive fluid is secreted in the large intestine, but many katabolic products are there returned to the digestive tract. Often the food remains in the large intestine for some time and becomes more solid, much of the water being absorbed. It is finally passed out through the anus as feces. The feces consist of the undigested residue of the feed, the remains of the digestive secretions, waste material resulting from wear and tear on the digestive tract, certain excretory products, and the bacterial flora.

Chemistry of Digestion

Water requires no digestive process. It is simply absorbed by the capillaries of the villi of the entire digestive tract. The *mineral*

matter also passes into the blood stream without being acted upon by digestive enzymes. Some of the minerals may be taken up in organic combinations, but most of them are brought into solution, to a greater or lesser extent, by the hydrochloric acid of the gastric juice or by other agencies.

The proteins are first acted upon by the pepsin of the gastric juice in the stomach. They are there broken down to proteoses and peptones. The trypsin of the pancreatic juice also breaks down proteins and converts them chiefly into proteoses and peptones, although it may convert some of them into amino acids. The erepsin of the succus entericus works on the proteoses and peptones and converts them into amino acids, which are the final products of protein digestion.

Of the carbohydrates, the starch is broken down to maltose by the enzyme amylase. The compound sugars are then converted into the simple sugars by the invertase enzymes, maltase, lactase, and sucrase—maltose forming two molecules of glucose; sucrose, one molecule of glucose and one of levulose; and lactose, one molecule each of glucose and galactose. The cellulose and pentosans, however, are not attacked by the enzymes secreted by the walls of the digestive tract. The digestion of the cellulose and pentosans is a process of fermentation, brought about by enzymes secreted by bacteria which accompany the food. This occurs in the paunch. The products of fermentation are gases, such as methane and carbon dioxide, which cannot be used as food, and organic acids, such as butyric, acetic, and lactic, which may be taken up and used as food.

The fats are not acted upon to any extent until they reach the small intestine. Here they are hydrolyzed into glycerol and fatty acids by the enzyme lipase, which is secreted in the pancreatic juice. The bile causes emulsification to take place. If there is some free alkali in the digestive tract it may unite with the fatty acids, converting them into soap, but not all the fatty acids are converted into soap.

The process of digestion is complete when the proteins have been converted into amino acids, the starches into simple sugars, and fats into glycerol and fatty acids.

DIGESTIBILITY OF FOODSTUFFS

The word "digestion" is used to include all the processes necessary for the conversion of food into the soluble forms in which it is assimilable. However, not all the food can be converted into soluble forms so that it can be absorbed. To determine what portions of a food may be absorbed, digestive trials are run. For this purpose it is necessary to analyze the foods consumed and the feces excreted; the difference between what is fed and what is excreted is said to be the digestible food. The coefficient of digestibility is the percentage of food that is digested. The sheep and the steer have been used more often than any other animals in digestion trials for the determination of the coefficient of digestibility. The dairy cow has not been used so often because it is difficult to harness her in such a way that the liquid portion of the excreta is kept separate from the solid portion. When dairy cows are used it is essential that they be watched constantly in order to make such separation. For the proper conduct of a digestion trial, samples are taken from six to ten days after a preliminary period of two weeks. It is necessary that several days' collection of excreta be taken in order that a satisfactory average may be secured. Aliquot portions of the daily excreta are saved and composited for the final sample.

Table VI [1] gives the chemical analysis of the dry matter of the hay fed to a steer and of the feces of the steer in a digestion trial at the Pennsylvania Experiment Station.

TABLE VI

ANALYSES OF DRY MATTER OF HAY FED TO STEER AND FECES OF THE STEER AT THE PENNSYLVANIA EXPERIMENT STATION

	Ash per cent	Protein per cent	Non-protein per cent	Crude Fiber per cent	Nitrogen-free Extract per cent	Ether Extract per cent
Timothy hay....	5.82	7.11	0.50	34.06	50.73	1.78
Feces..........	6.60	10.71	0.00	34.61	46.02	2.06

[1] U.S.D.A. An. Ind. Bul. 128.

The animal was fed 3000 grams of timothy hay per day; but after the residue was subtracted the amount eaten daily was 2647.2 grams. The average daily weight of the feces collected was 1199.1 grams. From these figures it can be calculated that the amount digested was as given in Table VII.

TABLE VII

AMOUNT OF FEED DIGESTED AND COEFFICIENT OF DIGESTIBILITY OF DRY MATTER OF TIMOTHY HAY FED TO STEER AT PENNSYLVANIA EXPERIMENT STATION

	Ash lb.	Protein lb.	Non-protein lb.	Crude Fiber lb.	Nitrogen-free Extract lb.	Ether Extract lb.
Timothy hay....	154.1	188.2	13.2	901.6	1342.9	47.1
Feces..........	79.1	128.4	00.0	415.0	551.8	24.7
Digested.......	75.0	59.8	13.2	486.6	791.1	22.46
Coefficient of digestibility....	48.67	31.77	100.0	53.97	58.91	47.56

It is assumed that the feces contained only undigested food. This, of course, is not strictly true, since many metabolic substances are added from the blood and from the excretions which enter the digestive tract, and there is no method of determining these metabolic products; hence, that which is really apparent digestibility is called digestibility. Since some of the minerals, especially calcium, phosphorus, iron, and part of the magnesium, are excreted mainly through the intestines, this method cannot be used to determine their digestibility.

Factors Influencing Digestibility.—Several factors influence digestibility. Animals of different species vary widely in the percentage of food digested, but animals of the same species are nearly the same in this respect. There is very little difference between the various breeds of dairy cows. The main differences are individual ones and are due to faulty teeth, diseased digestive organs, intestinal worms, etc.; but these differences rarely exceed 3 or 4 per cent. In the young calf the first three stomachs are not well developed,

and until the calf is old enough to eat roughage it cannot ruminate and properly develop these stomachs. After the stomachs are fully developed, the age of the animal seems to have far less influence on the percentage of food digested. Heavy feeding seems to decrease the digestibility of the food, probably because of the greater bulk, the relatively rapid passage through the digestive tract, and the consequent lessened extent of bacterial fermentation. Roughages as a rule are less digestible than concentrates because the large amounts of crude fiber in such feeds tend to protect them from the action of the digestive juices. Palatability may have some effect on digestibility since it has been shown that palatability influences the secretion of the digestive juices. Feeders practice cooking, soaking, grinding, and the use of condiments, with the idea of increasing digestibility. Grinding does increase digestibility, especially of hard seeds, which otherwise would go through the digestive tract unbroken. Grain should, therefore, be ground when fed to dairy cows. The cutting of roughage or the soaking of feeds apparently does not increase digestibility.

Total Digestible Nutrients.—The total digestible nutrients of any feeding stuff are determined by taking the sum of the digestible crude protein, the digestible carbohydrates, and 2¼ times the digestible fat. The total digestible nutrients are simply the nutrients of the feeding stuff converted into carbohydrate equivalents. On the average, fat contains about 2¼ times as much energy as carbohydrates, and protein contains about the same amount as carbohydrates.

Since protein has certain functions which cannot be performed by the other nutrients, the percentage of digestible protein is usually given along with that of the total digestible nutrients, although it should be borne in mind that the digestible protein is included in the total digestible nutrients.

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LECTURE IV

THE USE OF FOOD IN THE BODY

Absorption

The food within the intestines is spread out in thin layers over the intestinal surface. The surface is increased many times by the finger-like projections, called villi (singular, villus), which line the walls of the intestines. Each villus is supplied with an artery, a vein, a capillary, and a lacteal. The mucus of the villi is very thin. The villi are able to expand and contract and thus take up the material from the intestines like a sponge. Just how the food is taken up by the body is not fully known. The laws of diffusion and osmosis explain to a large extent the theory of absorption, yet it is believed that living protoplasm is essential to this process.

The food can enter the blood stream in either of two ways: by the portal vein and the liver; or by the lacteals into the lymphatic circulation which empties into the blood by means of the thoracic duct.

The amino acids resulting from the breaking down of the proteins pass through the cell wall unchanged and enter the blood stream by the portal vein. The simple sugars and organic acids also enter the blood stream by the portal vein. The fatty acids and glycerol are changed back to glycerides as soon as they enter the body. These glycerides then go into the lymph system in a very fine state of emulsion and later enter the blood stream by means of the thoracic duct. After a meal rich in fat, the chyle in the lymph system, flowing away from the digestive system, is white in color. Although a large part of the absorption takes place in the small intestine, some of the nutrients also enter from the large intestine.

Circulation

The Blood.—In the process of digestion the food is converted into simple compounds which must be carried to the parts of the body where they are needed. This is done by means of the blood

circulation. The central organ of the circulation is the heart, which is divided into four quarters. The nutrient-rich blood coming to the heart enters the right auricle and from there is forced into the right ventricle. This contracts and forces the blood out through the lungs, where it is relieved of its carbon dioxide and takes on a supply of oxygen. The blood then returns to the left auricle, whence it is forced into the left ventricle, which, by contracting powerfully, drives the blood through the aorta and the subdividing arteries to all parts of the body. The arteries divide repeatedly into smaller branches, and finally carry the blood to the capillaries. It is through the capillaries that the cells receive their supply of oxygen

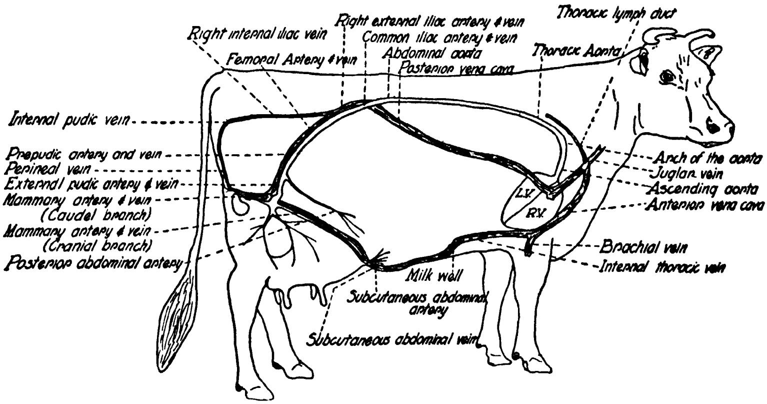

FIG. 4.—Circulatory system of the cow (schematic). A single large artery supplies blood to both the rear and front quarter of the udder. Three distinct veins carry the blood back to the heart. (*Turner.*)

and food and unload their waste products. From this point the blood returns to the heart through the veins.

The blood has many important functions, among which are the carrying of digested food from the digestive tract to the tissues, the carrying of oxygen from the lungs to the tissues, and the carrying away of all waste products of the cells to the proper place of disposal. The blood serves to keep the heat of the body evenly distributed, and it transfers water from one part of the system to another. All internal secretions are carried by the blood.

The blood is a red, opaque, rather viscous fluid. It is alkaline in reaction. The shade of red depends upon whether the source of

the blood is an artery or a vein. According to Sussdorf,[1] blood forms about 7.7 per cent of the weight of a living cow's body. It is composed of serum, red corpuscles, white corpuscles, blood platelets, and fibrin. The number of red corpuscles in the blood is enormous, being estimated at 4 to 6 million per cubic millimeter. They contain as a characteristic ingredient the conjugated protein hemoglobin. The hemoglobin carries the oxygen from the lungs to the tissues, the blood serum carrying the food.

The Lymph.—The body cells are not closely packed together but are surrounded by a colorless, transparent fluid known as lymph. From it, by osmosis or in other ways, the cells receive their food, and into it they deposit their waste. The lymph in turn is separated from the blood only by the thin walls of the capillaries, through which the body is supplied with its food and eliminates its waste. The lymph spaces unite to form the lymphatic system which empties into the jugular vein in the lower left side of the neck.

Metabolism

The cell, as defined by Armsby,[2] is the biological unit of life. The cells are the laboratories of the body, within which extensive chemical reactions take place. In them the food is either built up into body tissue or broken down to serve as a source of energy, as the case may be. The sum total of the chemical changes which the food undergoes in the body is known as *metabolism*. Those processes by which simple materials are built up into more complex ones are spoken of as *anabolism;* those by which living matter is broken down into simpler substances are spoken of as *katabolism*. Whereas digestion is characterized by hydrolyses, metabolism in general is characterized by oxidation, although other forms of reaction are common. These reactions are thought to be brought about by intercellular enzymes, which are present in every cell and are able to alter the velocity of chemical reactions and thus to keep the mechanism of the body running smoothly. The final end and aim of metabolism is to supply energy for the vital activities of the body. The demand for energy is the controlling factor in the activities of the cells.

[1] A Manual of Veterinary Physiology, Smith.

[2] The Nutrition of Farm Animals, Armsby.

Ash Metabolism.—Very little is known concerning the metabolism of ash. As previously pointed out, many of the ash ingredients are essential to the vital processes of the animal body. It may be assumed that they enter the body either in solution as inorganic salts or in combination with organic substances. It has been found that sulphur is taken into the body largely in organic combinations and is built up in the body as such. Inorganic sulphur cannot be used by the animal. Phosphorus is probably taken into the body as phosphoric acid. Phosphorus, along with calcium, constitutes a large part of the bones, but it is also found in many other parts of the body and in organic combination. The cells seem to be able to use inorganic phosphorus for building up organic compounds. At least two other ash ingredients enter into organic combinations within the animal body. They are the iron of the hemoglobin, and the iodine of the thyroid gland. Little is known concerning the metabolism of any of the other ash ingredients, but it is thought that they go into solution and are taken up and used in that manner.

Protein Metabolism.—As previously noted, the proteins are absorbed in the form of amino acids. These are carried in the blood to the parts of the body where they are needed, and there they are built up into new proteins peculiar to the tissues in which they are formed and different from the proteins from which they were derived. Each individual cell seems to have the power of building up these compounds through a condensation process. Here they are used in the repair and synthesis of tissue.

In the katabolism of proteins, two general stages are recognized. The first stage is one of hydrolysis by which the proteins are broken down into amino acids; in the second stage the nitrogen is split off from these acids as ammonia. This process is known as deaminization. The ammonia resulting from it is rapidly converted into urea or, in the Herbivora, largely into hippuric acid, in which form it is excreted from the body by means of the urine. The residue of the amino acid, after the removal of the ammonia, is closely related chemically to both the carbohydrates and the fats, and may, like these, be used to supply energy, or, as has been shown with some of the amino acids, may be converted into glucose. It is probable that fat can be formed from protein, but the amount of fat thus formed

under normal conditions is insignificant. All these reactions are supposedly brought about by intercellular enzymes.

The non-protein nitrogen-containing material, consisting chiefly of amides and amino acids, probably enters the body in the form of amino acids and is used as such.

Carbohydrate Metabolism.—Glucose, levulose, and galactose pass through the portal vein and are carried to the liver and tissue. Here, by a process of condensation, they are changed into a polysaccharide, glycogen. The liver acts as the principal storehouse of glycogen, although some of it is stored in the tissues. As much as 10 to 15 per cent of the weight of the liver may be glycogen, and about one-half of this amount may be stored in the tissues. No glycogen is found in the blood. If more glucose is provided than the liver and muscles can take care of at once, it is eliminated through the urine. The amount of glucose in the blood is from 0.1 to 0.2 per cent, but remains remarkably constant and seems to be regulated by the supply stored in the liver and tissues. If the supply of glucose from the intestine is insufficient to maintain the normal supply in the blood, the glycogen is changed by hydrolysis into glucose and thus the supply of glucose in the blood is kept constant. It is believed that this reaction is brought about by intercellular enzymes. A hormone (insulin) produced by the pancreas is required for the oxidation of the glucose in the body. The removal of the pancreas results in the loss of glucose through the kidneys, as in diabetes. Much of the energy used by animals to warm their bodies, to do muscular work, and to produce milk comes from the oxidation of glucose and the simple sugars. In ordinary feeding stuffs, one-half to two-thirds or even more of the oxidizable material consists of carbohydrates, which when digested are taken up as simple sugars. Also, about 60 per cent of the protein and 10 per cent of the fats are believed to be converted into glucose in the course of metabolism.

According to Shaffer,[1] glucose may be burnt during metabolism into carbon dioxide and water, with or without an intermediate conversion into glycogen; or it may be converted into fat by reduction. The path of glucose metabolism is through a series of reactive compounds; and it is these substances resulting from molecular rear-

[1] Physiol. Review, 3:394.

rangements which are finally oxidized, liberating energy, or are synthesized into fat and other substances. According to the generally accepted view, lactic acid represents the main intermediate in glucose metabolism, and it is with this substance that oxidation actually begins. Jordon and Jenter [1] have demonstrated that with dairy cows much of the milk-fat is produced from carbohydrates.

The organic acids resulting from the fermentation of the celluloses and pentosans enter the body without change. The lactic and acetic acids can be used directly for energy, and the others are probably changed into forms in which they can be used.

Fat Metabolism.—The fatty acids and glycerol, upon entering the lymphatic circulation, are changed back to glycerides and in this state are carried as a fine emulsion through the thoracic duct, which empties into the blood stream in the neck. Just how the blood carries the fat is not fully known. Bloor [2] states that the red blood corpuscles take up the fat from the plasma and transform it into lecithin and that lecithin is an intermediate step in the metabolism of fats. Gage and Fish [3] were able to follow the very minute particles of fat emulsion, which they call chyle microns, in the blood through the entire body, by the aid of a high-power dark-field microscope. They found that these particles appeared in the blood ½ to 1½ hours after eating and that after 6 to 8 hours they had disappeared from the blood. They also found, by means of dyes, that the source of the fat in the milk of dairy cows was not the fat in the food, although it seemed to be in the goat and some other animals.

The fat is stored in the adipose tissues and can be used as a source of energy when needed. It has been shown that, when the food supply is inadequate, the stored fat is drawn upon for the support of the internal activities of the body and as a source of energy. The exact chemical changes which take place are not known, but it is probable that different lipase enzymes which are widely distributed in the body break up the fat into glycerol and fatty acids, which are then oxidized. The final products of this oxidation are carbon dioxide and water. Whether fat can be converted into glu-

[1] N. Y. Exp. Sta. Bul. 132.
[2] Jour. Biol. Chem. 24:449.
[3] Am. Jour. Anat. 34:1.

cose is not fully known. It is thought, however, that at least the glycerol part can be so converted.

Paths of Excretion

The vital activities of the body lead to the formation of products which must be removed. The most common of these are carbon dioxide, water, urea, and some mineral ingredients. An accumulation of such products tends to stop the vital activities of the cells.

Carbon dioxide is mainly given off through the lungs, but a small amount is excreted through the skin. It is carried to the lungs by the blood. Water is removed by evaporation from the lungs and from the surface of the body. According to Armsby,[1] a 1000-pound steer, at an ordinary temperature and on light feed, may easily excrete through the lungs and skin 8 to 10 pounds of water in 24 hours. The feces also contain a large amount of water. Water is likewise excreted in the urine, serving as a solvent for the nitrogenous products of cell activity.

The urea and other nitrogenous materials which result from protein katabolism are excreted mainly through the urine. Most of the mineral ingredients, especially sulphur, chlorine, and the alkalies, are also excreted through the urine; but the intestines are the usual path of excretion of calcium, phosphorus, iron, and to some extent, magnesium.

Determination of the Use of Food in the Body

The coefficient of digestibility tells the percentage of the food that is assimilated by the body, but it does not tell what use the animals make of the nutrients, after they are once within the body. This has to be determined by a complete balance of nutrition, in which the entire intake is balanced against the entire outgo. The intake includes air, food, and water; the outgo includes the feces, urine, gases, and heat. By measuring each of these, it is possible to determine exactly how much of the gross energy of the feed the animal has been able to use for growth, fattening, work, or milk production.

[1] The Nutrition of Farm Animals, Armsby.

The Respiration Calorimeter.—Several forms of respiration apparatus, permitting a very exact determination of the gaseous exchange, have been constructed; but only when a respiration calorimeter was built at the Pennsylvania Experiment Station, in 1898, was it possible to combine with a determination of the respiratory products a direct measurement of the heat given off by a domestic animal, such as the dairy cow.

The respiration calorimeter at the Pennsylvania Experiment Station [1] consists of a stall, constructed of sheet copper, and large enough to hold a cow or steer comfortably. It is completely air-tight. Under the rear portion of the stall there are receptacles, enclosed in a small, air-tight chamber, for collecting the feces and urine which are conducted to them by means of rubber tubes. This chamber is closed with an air-tight door. The feed and water are put into the stall through an air-tight door in the front. All the doors are kept tightly closed except when the animals are being fed and watered, or the excreta removed. This requires only a few minutes each day. Samples of the feed and excreta are taken and analyzed. Exact records of their weight are also kept.

The air is measured, sampled, and analyzed for water, carbon dioxide, and methane, both as it enters and as it leaves the stall. The heat given off is also measured. It is thus possible to determine accurately the expenditures of an animal.

Table VIII shows how it is possible to compare the income and outgo of energy and get the balance of energy by means of the respiration calorimeter.

Metabolizable Energy.—The animal body may be compared to a gasoline engine, requiring, first, repair material to keep it in good running order, and second, fuel or energy with which to do its work. The working part of the body is furnished by the water, protein, and ash; the energy is supplied by the carbohydrates and fats, although the protein also furnishes energy during its katabolism. The total energy furnished in the feed is the gross energy. However, not all of this is available to the body, as some is lost in the feces, some in the urine, and some in the gases which escape from the body. The metabolizable energy is that part of the gross energy which is not

[1] Pa. Exp. Sta. Bul. 104.

TABLE VIII

DAILY ENERGY BALANCE OF A STEER *

	Income, calories	Outgo, calories
6,988 grams timothy hay	27,727	
400 grams linseed meal	1,811	
16,619 grams feces	......	14,243
4,357 grams urine	......	1,210
37 grams bushings	......	88
142 grams methane	......	1,896
Heat	......	11,493
Gain in body	......	608
	29,538	29,538

* The Nutrition of Farm Animals, Armsby.

carried off in the urine, feces, or gases. In other words, it is the energy that is capable of transformation in the body.

Net Energy.—It has been found by means of the respiration calorimeter that some energy is spent in the work of digestion. This is especially true of the Herbivora, since they consume a large amount of rough feed. The metabolizable energy minus the energy required for the work of digestion is known as the net energy. Armsby defines the net energy value of a feeding stuff as the energy remaining after the losses of chemical energy in the various excreta

TABLE IX

DETERMINATION OF NET ENERGY VALUE OF TIMOTHY HAY *

	Dry Matter of Hay Eaten, pounds	Metabolizable Energy, calories	Heat Produced, calories	Gain of Energy, calories
Period 4	10.21	9544	9812	− 268
Period 3	6.17	5768	8064	−2296
Difference	4.04	3776	1748	2028
Difference per pound dry matter of hay	.....	935	433	502

* The Nutrition of Farm Animals, Armsby.

and also the energy expended in the processes incident to the consumption of the material have been deducted from its gross energy.

An example of the method of determining the net energy value of a feeding substance is given in Table IX. In the balance experiments with a steer, two different amounts of timothy hay, both insufficient for maintenance, were fed during successive periods.

Here the net energy of 1 pound of dry matter was 502 calories. This is the amount of energy that the animal actually has left, with which it may do work, put on fat, or produce milk, as the case may be.

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LECTURE V

MILK SECRETION

THE food which enters the body of the dairy cow is used not only in building up tissue and performing work but also for the production of milk. For this purpose a large amount of food is necessary. The blood carries the food material to the udder of the cow, where it is collected and changed into the components of which milk is composed, some of which are found nowhere else in nature.

STRUCTURE OF THE MATURE UDDER [1]

The udder of a cow is normally composed of four mammary glands, two (the fore and rear quarters) in each half. There may be one or more supernumerary teats, with small glands, but these glands usually do not develop. The right and left halves of the udder are separated by a well-defined longitudinal groove which extends upward as the medium connective tissue septum. As viewed from the side, the udder should have a rounded, saccular appearance with attachments extending high behind and carried well forward.

Upon dissection, each half of the udder is found to be enclosed in a strong, fibrous sac. On the inner side where the halves join, the fibers intermingle and extend upward to the abdomen where an attachment is made. This structure is known as the median suspensory ligament. On each side of the udder are found the lateral suspensory ligaments which, together with the skin, serve as the chief support of the udder. Any weakness in the central support will cause the teats to stick out or "strut," as it is sometimes called; and a weakness in the lateral suspensory ligament causes the udder to break down.

The quarters in each half of the udder are not as distinctly separated as the halves. However, they are divided by a very thin

[1] Mo. Exp. Sta. Bul. 344 and 346.

connective septum, irregular in outline, which permits no mingling of the secretion of the two glands.

The entrance from the outside to the udder is through a canal (streak canal) which is $\frac{1}{4}$ to $\frac{3}{8}$ inch in length. This canal is kept closed by a circular sphincter muscle near its outer end. This muscle serves to keep the milk in the udder, against the pressure developed by milk between milkings, and also keeps bacteria and other foreign material out of the udder. If this canal is small, or if the sphincter muscle is unusually tight, the cow is a "hard milker." If this muscle is not held tight, the udder will leak milk and the cow will be a "leaker."

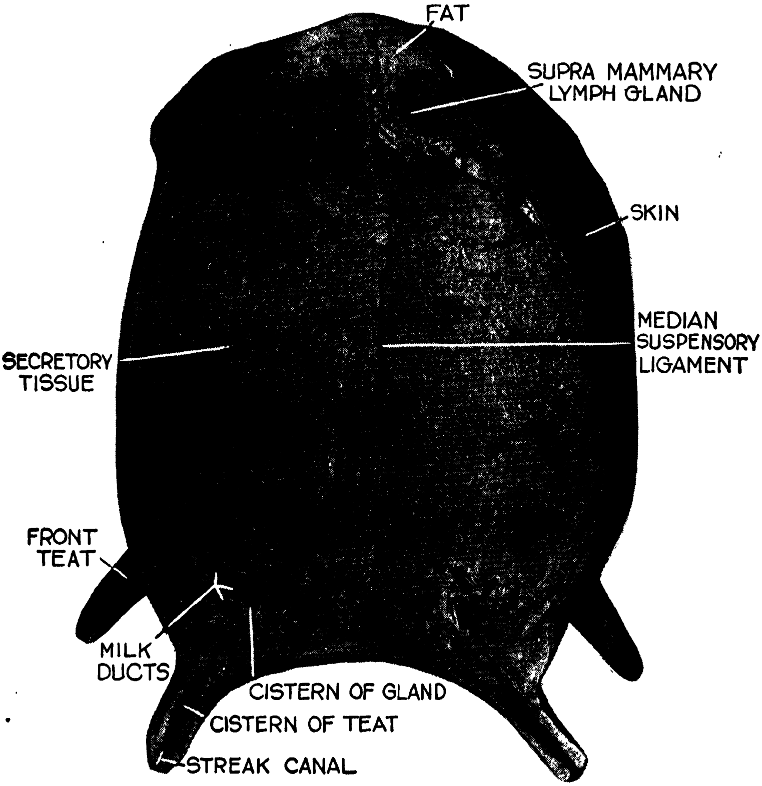

FIG. 5.—Cross section of the rear quarter of a cow's udder. (*Turner.*)

The streak canal opens into the milk cistern, the function of which is to act as a reservoir for the milk during the period between milkings. The milk cistern is an opening of considerable size, varying somewhat in size and shape with different individuals. Into the cistern eight to twelve large milk ducts lead. These ducts branch very irregularly. In some cases the duct branches into two ducts of equal size; in others, smaller branches are given off from the main duct. These ducts continue to branch until they become quite small, and finally end in an enlargement which is called an alveolus or acinus. A good comparison is to consider these alveoli as grapes and the ducts as the branching stems. A group of alveoli, corresponding to a bunch of grapes, is called a lobule, and a group of lobules forms a lobe.

These various divisions of the gland tissue are surrounded and supported by bands of connective tissue. Sometimes the connective tissue develops excessively and forms a large fibrous udder, often called a "meaty udder." Such udders, on account of their size, often give the impression that the cow is a heavy milker. This may not be so, as this connective tissue does not aid in milk secretion. An udder with less connective tissue and more secretive tissue is to be preferred.

Milk secretion occurs in the layer of epithelial cells lining the alveoli. These cells increase in size during the period between milking. The ducts of the udder, lined by two layers of epithelial cells, act as a storage for the milk between milkings.

The Mode of Milk Secretion

As has been shown, the tiny epithelial cells in the alveoli are the factories in which the constituents carried by the blood are taken out of the blood capillaries and are synthesized (when necessary) into the component parts of milk, namely, fat, lactose, protein, minerals, vitamins, and all the other constituents of milk. In some way as yet unexplained, these cells have the unique ability of changing or manufacturing materials entirely different from those from which they came. It has been shown, as would be expected, that, as the blood passes through the udder, the content of amino acids, glucose, and fat in the blood appreciably decreases.

It is believed that each cell in the alveoli can manufacture all the milk constituents, and that there are no specialized cells for each type of compound. The gradual synthesis of milk causes the epithelial cells to lengthen, and fat globules begin to collect in the end of the cell facing the inside cavity, or lumina, of the alveolus.

The opinion of investigators differs concerning the method by which the milk, when secreted, passes from the cells of the alveoli to the ducts. Some believe that the milk constituents, by the process of osmosis and dialysis, pass through the cell wall, leaving it intact. Others believe that the cell wall ruptures to let the milk constituents escape.

Following the milking process, as soon as the milk is removed from the udder, the cycle of milk secretion and discharge by the epithelial cells begins, filling the lumina of the alveoli, the ducts, and the milk cistern. During the first period the secretion is rapid, but as soon as the storage spaces fill up, the pressure increases and secretion slows down. Milk is not formed as rapidly as it was when the udder was empty or nearly so. This explains why heavy milking cows will secrete considerably more milk if milked three or four times per day than they will if milked only twice. With cows not milking heavily, the increase of milk production due to increased number of milkings is not so great as with the heavy producers.

That milk secretion is a continuous process has been shown by several investigators. Cows have been slaughtered immediately before the usual milking time, their udders have been removed, kept at body temperature, and milked out thoroughly in the usual manner. An experiment [1] conducted along this line showed that 70 per cent as much milk could be obtained as was obtained on the corresponding previous milking. In one experiment the udder was removed as described above and analyzed for lactose, with the result that more lactose was obtained than was contained in the milk yielded in the previous corresponding milking. This was due perhaps to the fact that it is almost impossible to obtain all the milk from an udder by ordinary milking.

[1] Jour. Agr. Res. 45:401.

Milk Formation

In feeding cows for milk production, it must be borne in mind that the same type of food is used for milk production as for growth and maintenance, and that the mammary gland has the ability to take the food from the blood and change it into the constituents of milk. The individual compounds found in the milk vary greatly from those found in feed or in the cow's body.

Proteins.—There are three well-recognized proteins in milk, namely, casein, albumen, and globulin. Casein, the principal protein, is unique in that it is found nowhere else in nature. Albumen and globulin are found in the blood, but the albumen in the milk differs from that found in the blood and hence must be manufactured from the amino acids carried in the blood. The globulin in milk is the same as that found in blood and hence may be obtained directly from the blood.

Milk Sugar or Lactose ($C_{12}H_{22}O_{11}$).—Milk sugar is formed by the union of two simple sugars, glucose and galactose, and like casein is found nowhere else in nature. The milk gland seems to be able to change the glucose found in the blood into galactose. When lactose is injected into the blood stream, it is not used by the mammary gland but is excreted in the urine.

Fats.—Milk fat is a mixed fat composed of the glycerides of ten or more fatty acids, and contains many of the fatty acids of low molecular weight. The fat-like substances of blood include neutral fat, fatty acids, phospholipoids (lecithin), and cholesterol. Recent evidence indicates that milk fat is made from the triglycerides of the blood. Many of the fats found in milk are found nowhere else in the body, and hence they must be synthesized in the cells of the udder.

Minor Constituents.—The minerals found in milk are also found in the blood and are probably taken out as the blood passes through the udder. They may be used in organic combinations or as they exist in the blood. The vitamins, also, are not synthesized by the milk gland but pass through from the blood stream.

"Holding Up" the Milk

Cows sometimes refuse to "let down" their milk after the usual manipulation at the time of milking. This may occur at the beginning of the milking period after the milk in the milk cistern has been removed, or it may occur later during the milking period, but before the milk is completely removed. In either case it is difficult to get all the milk from the udder.

This condition is usually caused by some unusual condition around the barn which causes the cow to become nervous. The removal of her calf after freshening will sometimes make the cow nervous and uneasy, so that she will "hold up" her milk. Excessive noises, barking of dogs, or strangers around the barn sometimes cause this trouble. Painful sores or injuries of the teat or udder may be a cause. Unkind treatment, such as kicking or beating a cow, is almost sure to make the cow hold up her milk. Irregularity of feeding or milking is another cause.

It would seem that a cow does not wilfully "hold up" her milk. The secretion of milk is an entirely involuntary action, but the "letting down" of the milk is brought about by a nervous response to the normal stimulation of milking. The involuntary muscles of the udder contract, forcing down the milk. The continuous manipulation of the teats furnishes sufficient nervous stimuli to maintain the contraction of the muscles and the resulting milk pressure. If the cow becomes excited at milking time this contraction of the muscles does not occur, and the pressure within the udder does not increase. When such a condition occurs, it is useless to continue milking until the cow has "calmed down." Cows handled gently and regularly will seldom "hold up" their milk.

The Development of the Mammary Gland

In the young dairy animal before sexual maturity the mammary gland is but slightly developed. The milk ducts are small and short and have very few branches. With sexual maturity, however, the gland begins to develop and the ducts to lengthen and branch out into the fatty tissue that makes up the udder at that time.

Effect of Estrogenic Hormone.[1]—Closely associated with the early development of the udder and with milk secretion are certain hormones. The first of these is the estrogenic hormone which causes heifers to come into heat. This hormone, usually called estrogen, is secreted by the cells of the ovary into the follicular fluid, from which it passes into the blood. It stimulates the growth and branching of the milk ducts which lead out from the milk cistern. This seems to be done indirectly, as it actually stimulates the anterior pituitary to secrete a hormone or hormones to act upon the udder. Eventually it is excreted from the body through the urine.

FIG. 6.—External change in the udder of a heifer during the first pregnancy. (*Turner.*)

With each successive heat period these ducts increase in size, but there is no development of the true secreting tissue, the alveoli. The duct system at this stage of growth is like the trunk and larger branches of a leafless tree.

Effect of the Hormone Progestin.[2]—After the heifer conceives, there is a rapid growth and extension of the duct system to all parts of the udder. Many side branches form, upon which the alveoli develop. This growth is like the leafing out of a tree in which the alveoli represent the leaves and the ducts the branches of the tree. This enlargement and growth is caused by a second hormone, progestin, which works in combination with estrogen. It

[1] Mo. Exp. Sta. Bul. 339; Mo. Exp. Sta. Res. Bul. 145.

[2] Mo. Exp. Sta. Res. Bul. 174.

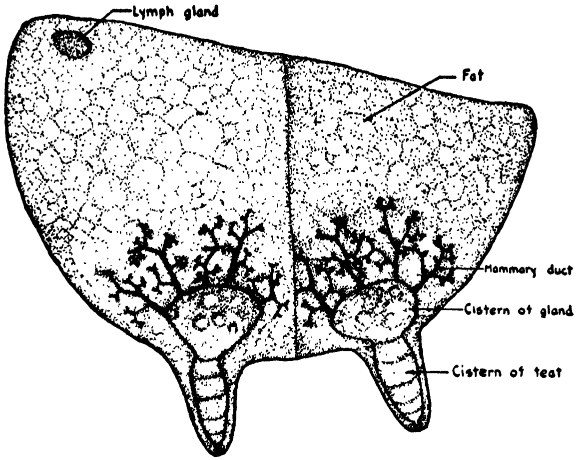

FIG. 7.—Diagram of a cross section of the udder of a heifer before revealing maturity. At this stage the glands consist of a small teat and milk cistern. The ducts leading out from the cistern are small and short with few branches. (*Turner.*)

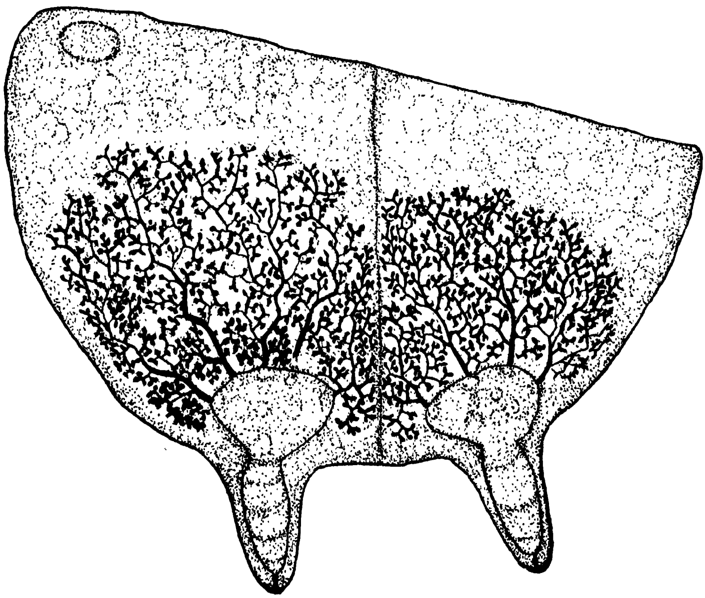

FIG. 8.—Diagram of a cross section of the udder after many "heat periods." The duct system shows extensive development but the lobule-aveolae system is not stimulated to growth. (*Turner.*)

is secreted by the corpus luteum or "yellow body" in the ovary of the pregnant animal. About 24 to 36 hours after the heifer comes into heat, the egg or ovum is discharged and carried into the fallopian tube, down which it passes into the uterus where it may be fertilized. After the discharge of the egg or ovum, there is a rapid growth in the ovum follicle of a cell containing a deep yellow or orange pigment. This is known as the corpus luteum or yellow

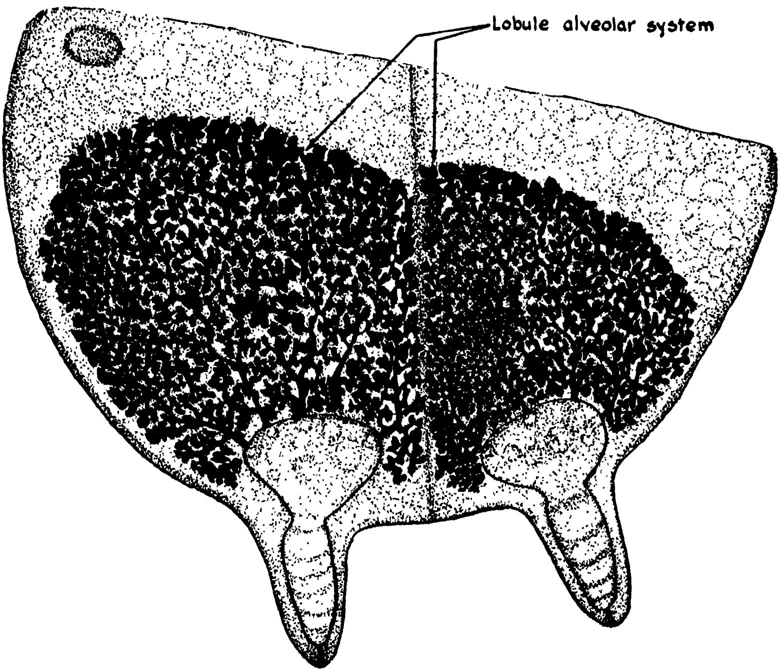

FIG. 9.—Diagram of a cross section of the udder of a heifer at about the fifth month of pregnancy. From the ducts shown in Fig. 8, the lobule-aveolae system has grown owing to the combined stimulus of estrogen and progestin. (*Turner.*)

body. If the heifer is not bred, this soon disappears and new cells secreting the estrogen develop; but if she conceives, the corpus luteum is retained in the ovary during pregnancy and secretes the hormone progestin.

Effect of the Lactogenic Hormone.—The enlargement of the ducts and the development of the alveoli continue until about the middle of pregnancy when their growth has largely been completed. The cells of the alveoli then begin to secrete a fluid resembling

colostrum milk, the milk first secreted after a cow freshens. This secretion of milk is brought about by a third hormone,[1] the lactogenic hormone, known as lactogen or galactin. This hormone is secreted by the anterior lobe of the pituitary gland located at the base of the brain. During the latter half of the gestation period little growth takes place, but the enlargement of the udder is largely due to the accumulation in the duct system and alveoli of the secretion which is later given in the form of colostrum milk after the animal freshens.

The mechanism which initiates the stimulus for milk secretion during the second half of pregnancy, yet holds in check the extensive secretion of milk until parturition occurs, is not fully understood; but it is supposed that some substance in some way acts as a check until after parturition, at which time it disappears, giving the lactogenic hormone a chance to act fully.

During the normal lactation period the yield of milk increases for a few weeks after calving, and then gradually decreases until the cow is dry. As the period of lactation advances the cells in the outer zone of the udder cease to secrete milk, while those around the larger ducts are still active. When the cow finally becomes dry, the alveoli degenerate, leaving only the milk cistern and duct system. This is rebuilt during the dry period.

Importance of the Pituitary Gland in Milk Secretion

The pituitary gland, also known as the "hypophysis," is a small structure located near the base of the brain. It is made up of three parts—the anterior lobe, the intermediate lobe, and the posterior lobe. This gland secretes other hormones besides the lactogenic hormone which have pronounced physiological effects upon the animal. A hormone secreted by the anterior lobe controls the growth and development of the animal, thus determining its mature size. Another hormone secreted by the posterior lobe stimulates the contraction of the involuntary muscles. Still other hormones secreted by this gland seem to influence the activity of the thyroid gland, the adrenal gland, and the metabolism of carbohydrates, fats, and proteins. Thus, by speeding up and regulating the body processes,

[1] Mo. Exp. Sta. Res. Buls. 158 and 196.

these hormones indirectly influence milk production of dairy cows. That such is true has been shown by several investigators. The injection of the pituitary hormone into dairy cattle has resulted [1] in an increased milk yield in certain series of as much as seven or more liters of milk per day. The increase was temporary but was sufficient to more than pay for the cost of the injection. The effect seemed to be greatest with well-fed cows and during the first half of the lactation period. No bad effects of any kind were noted in any case.

The difference in the productive ability of dairy cows might be explained by the difference in the amount of hormones secreted by the pituitary gland and by the other glands regulated by the pituitary.

Although the secretion of milk is an involuntary act, still the nerves in the udder do have an influence on lactation. The stimulus of milking causes the discharge of the lactogenic hormone and thus prepares for the stimulus of milk secretion during the interval between milking.

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LECTURE VI

SELECTION OF FEEDS

In order to feed dairy cattle most efficiently, it is necessary to know the characteristics and properties of some of the more important dairy feeds. The selection of feeds is important both from the standpoint of economy of production and from that of the health of the animals.

It is always best to use as many home-grown feeds as possible, and to buy only what is necessary to balance them properly. By this method the crops can be disposed of directly to the cow, and thus the expenses and losses due to marketing are avoided; and profits, which would otherwise be absorbed by purchasing feeds, are saved.

Feeds can be divided into two great classes:

1. Roughages.
2. Concentrates.

The roughages consist of silage, hay, and all the other coarse, bulky portions of the ration. The concentrates include the cereal grains and a great number of by-products of the milling and other industries.

LEGUME ROUGHAGES

Legume hay is especially valuable as a feed for dairy cows. This is due to the fact that it contains a liberal amount of high-quality proteins, a large percentage of calcium, and when well cured is rich in vitamins A and D. Some legume hay can be grown on almost any farm. By its use the cost of milk production can be kept down, since grain rations lower in protein content can then be used successfully.

Alfalfa.—Alfalfa hay is one of the very best roughages for dairy cattle. It is very palatable, and has a good effect upon the digestive system as it is slightly laxative. It is high in protein of excellent

quality, and is the highest of all common feeds in calcium. When properly cured, it is rich in carotene, the precursor of vitamin A.

Canada Field Peas.—Field peas are sometimes grown (either by themselves or more commonly with oats) for hay in the northern states. When cut at the proper time it makes a very nutritious feed, somewhat higher than red clover in protein but not so palatable.

Clovers.—Clover hay has the same advantages as alfalfa hay, except that it is a little lower in protein and is slightly less palatable. Four kinds of clover are grown extensively in the United States: alsike, crimson, red, and sweet. All have about the same feeding value, but alsike is finer in the stem, which makes it especially well adapted for feeding young calves. Sweet clover is hard to cure properly, and should be cut when the first blossoms appear, as the stems rapidly grow woody after this stage is reached. Although it has about the same feeding value as the other clovers, a much larger portion is usually refused by dairy cattle. It has been noted that when sweet clover is fed to cattle it may cause the loss of the clotting power of the blood. Animals fed heavily on sweet clover hay will sometimes bleed to death from internal hemorrhages or from outside wounds, such as dehorning or castration.

Cow Peas.—Cow-pea hay, when it can be properly cured, provides a roughage that is even better than alfalfa or clover, as far as protein is concerned. It is grown principally in the southern part of the United States as it is a warm-weather plant.

Lespedeza.—Lespedeza has been grown principally in the South and is adapted to land too acid or too poor to grow alfalfa or clover. Certain varieties have been developed which will grow farther north than the common lespedeza. Korean lespedeza grows as far north as Michigan. The hay is well liked by dairy cattle and is fairly high in protein and total digestible nutrients, but as a rule the yield is not high. The perennial species, *Lespedeza sericea*, is not quite as palatable as the annual, and is inclined to be stemmy, so that there is a greater waste.

Soy Beans.—Soy-bean hay, when properly cured, makes a very good roughage for dairy cattle. It is slightly higher in protein and total digestible nutrients than alfalfa, but it is usually coarser, and for this reason more is wasted. It is also high in calcium. It is

very palatable but, when allowed to get too ripe, has coarse, woody stems which the cows will refuse. It is slightly constipating in its effect. Its chief disadvantages are: first, that it is hard to cure properly; and second, that the cost of growing is usually higher than that of alfalfa as it must be seeded each year. However, it can be grown in some places where alfalfa can not. It is often seeded with sudan grass, sorghums, or millet, as it is then easier to cure than when sown alone.

NON-LEGUME ROUGHAGES

In general, non-legume roughages are not recommended as feed for dairy cows. They are low in protein, not very palatable, and are usually deficient in minerals and vitamins. They are used often, however, because of the ease with which they can be grown, and because otherwise they would be wasted. Since they do have some value, it is usually better to feed them than to allow them to waste. They can be fed in conjunction with a legume hay and a good grain ration.

Cereal Hay.—All the cereals—oats, wheat, barley, and rye—are sometimes used as hay crops. When cut early and well cured, they are fairly palatable and resemble timothy hay in composition. They are low in protein, and hence for dairy cattle should be fed with a protein supplement.

Corn Fodder.—Corn fodder, which includes both the grain and the stalk, is not very satisfactory as a feed for dairy cattle, especially if they are to be fed in the barn, as it is difficult to feed in the mangers. Because of its bulkiness, it is usually fed out-of-doors. It is unpalatable, low in protein, and, aside from the grain, is about equal to timothy hay in its nutritive value. There is considerable waste in feeding it as cows will not eat the coarse stalks.

Corn Stover.—Corn stover is corn fodder from which the ears have been removed. The same general statements can be made relative to corn stover as have been made concerning corn fodder. It is even less palatable than corn fodder, and is very low in protein. Its feeding value is about the same as that of timothy hay. Sometimes it is shredded. Although this does not increase its digestibility, it does decrease the waste and makes it much easier to store and handle; also, the refuse can be used as bedding.

Millets.—Millet ranks about the same as timothy in feeding value. It is less palatable, however, especially if allowed to become too ripe. It should be cut when in bloom, but at best is not a desirable feed for dairy cattle. It is used principally as an emergency crop.

Straws.—The feeding value of straws depends largely upon the method of growing and handling them. When grain is allowed to become entirely ripe, its straw is of little value for dairy cows in milk. When cows are fed on straws which are low in energy and digestibility, and are unpalatable besides, the best results cannot be expected. Straw, especially oat straw, may be given in limited quantities to young stock and breeding animals. *Oat straw* is to be preferred to all other straws, but it is low in protein, constipating, and very unpalatable; it is used only for bedding in the best dairies. *Wheat straw* and *rye straw* have no place in the feeding of dairy cattle but make excellent bedding. *Barley straw* is sometimes used for feeding. When barley straw of the bearded variety is fed, it is necessary to watch the cow's mouth to detect the accumulation of beards which may penetrate the sides of the mouth, thereby causing infection.

Sudan Grass.—When cut early, sudan grass makes a fairly good hay. It yields heavily and is fairly palatable. It is slightly laxative. It compares favorably with other non-legume hays in feeding value. When allowed to become too ripe, it is woody and not as palatable or as nutritious as when cut early. Often two crops can be harvested per year.

Timothy.—Timothy hay, although one of the most common roughages fed to dairy cows, is, as ordinarily harvested, low in protein, minerals, and vitamins. It is not very palatable and is constipating in its effects. When timothy is cut early, however, and from fields that have been nitrogen-fertilized, it is much higher in protein and much more palatable than the ordinary timothy hay. It cannot equal alfalfa or clover hay but may be used where these cannot be grown satisfactorily or economically. It is often grown with clover or alfalfa, the resulting hay being known as mixed hay, the feeding value of which is higher than that of timothy hay.

SUCCULENTS

It is usually recommended that some kind of succulent feed should be added to the dairy-cow ration for most profitable results. A succulent feed contains a high percentage of moisture and as a rule is palatable and has a good physical effect on the cow. These feeds, however, are low in nutritive value because of the fact that they are so high in water content. They are especially valuable because of the high yield of total digestible nutrients which they give on the acre basis.

SILAGES

Corn Silage.—Of all the crops used for the making of silage, corn is the most common. It can be harvested and put into the silo more easily, and is more certain of keeping than silage made from most of the other crops. Corn is as high in total digestible nutrients as any other crop used for silage, but it is low in protein. The moisture content of silage is high, averaging 74 per cent, leaving only 26 per cent dry matter. It is very palatable and is laxative in effect. It is low in minerals, however, and is not as high as might be expected in vitamins. It is not usually fed as a sole roughage, but should be combined with some legume hay which will help make up its deficiency in proteins, minerals, and vitamins. Three pounds of silage is usually fed to replace one pound of hay.

Corn Stover Silage.—Silage from dry corn stover is sometimes made by cutting it up the same as the green corn and turning water into the silo, thus giving it a succulent nature. The ears having been removed, the resulting silage is only slightly more than one-half as good as regular corn silage.

Legume Silage.—Clover, alfalfa, soy beans, and cow peas are used to some extent for silage, although in general they are not as satisfactory as corn. They are higher in digestible protein but not quite as high in total nutrients as corn silage. As a rule they do not keep well since it is hard to pack them tightly. When they are cut for silage, care should be taken that they do not contain too much moisture. It is usually better to harvest them in the form of hay, or by special methods, such as the addition of mineral acids or molasses. These methods will be described in a later lecture.

Sorghum Silage.—The sorghums make excellent silage, especially if allowed to stand until the grain is ripe. They are palatable and have a desirable effect on the cow. They will not yield quite as much as corn over most of the United States, but in the southern plain states they are used extensively.

Sunflower Silage.—Sunflower silage has been used extensively in parts of the country where, because of dryness or shortness of season, corn cannot be grown to advantage. The yield per acre is high, but it contains less dry matter and total digestible nutrients than corn silage. It is not as palatable as corn silage although cows soon learn to eat it.

Roots and Tubers

Carrots.—Carrots are sometimes used as a feed for dairy cows, but their yield is low and so their use is not general. They are

Fig. 10.—Mangels make excellent feed for dairy cows.

palatable, however, and being very rich in carotene, the precursor of vitamin A, have a tendency to color the fat in the milk.

Mangels.—Of all the root crops, mangels are the highest yielders and for this reason are the most commonly used. They are

used extensively in Europe. Even though their yield is very high, they have a very low dry-matter content, averaging only about 9 pounds of dry matter in 100 pounds of mangels. In this country they are used especially for cows that are being forced for heavy milk production, and they are unexcelled in adding succulence to a ration. They are fed at the rate of 40 to 80 pounds per day, depending upon the size of the animal. They should be fed more generally, especially where there are too few animals to justify the use of a silo or where the tillable acreage is limited.

Potatoes.—Potatoes have much the same general characteristics as the roots. They are slightly higher in nutritive value than the roots, being almost equal in that respect to corn silage. There is danger of bloat and indigestion if potatoes are fed in too large quantities.

Rutabagas.—Rutabagas have a little higher dry-matter content than mangels, and they keep a little better. In most of the United States they do not yield quite so well, however, and for this reason are not as widely grown. Unless care is taken they are likely to taint the flavor of the milk.

Sugar Beets.—Sugar beets are slightly higher in total nutrients than the other roots, but the yield is much lower than that of either mangels or rutabagas and for this reason they are not generally used. Beet tops are sometimes put in silos, where they make very satisfactory silage.

Turnips.—The yield of turnips is lower than that of mangels or rutabagas and hence their cost of production is higher. They are about equal in feeding value. Care must be exercised in feeding turnips, however, for their flavor will appear in the milk.

Miscellaneous

Pumpkins (Field).—The same general statement may be made of pumpkins as of the roots. Pumpkins rank about the same as the roots in food value, but there is considerable labor in their preparation for feeding. The idea that the seeds must be removed before feeding is erroneous, as they contain nothing injurious.

Apple Pomace.—Apple pomace, the residue left in the making of apple cider or vinegar, is sometimes available to those who live near cider mills. It gives about as good results as corn silage.

CONCENTRATES

It is possible to produce milk without feeding concentrates. Some dairymen make it a practice to produce the greater part of their milk supply during the summer, and to feed only roughage during the winter. It is also possible to produce fairly large yields of milk by feeding only roughage consisting of silage and alfalfa hay, or even alfalfa hay alone. To get a fairly large production, however, and to keep up the flow of milk over a long period of time, it is necessary to feed some concentrates. The cereals and leguminous seeds, together with the by-products, are known as the concentrates. If some of the grains can be grown on the farm, as they usually can, they will be found cheaper than purchased feeds.

Grains

Barley.—Barley is an excellent substitute for corn. It can be substituted for corn, pound for pound, with equally good results. It contains a little more protein than corn but is slightly lower in total digestible nutrients. It is used quite extensively in countries and localities where corn is not available. When fed heavily, especially in conjunction with alfalfa hay, it is said to cause cows to bloat. However, this is not often very serious.

Buckwheat.—The whole grain of buckwheat is not so desirable as the middlings from this cereal, because of the large amount of crude fiber or hulls that it contains. These, however, give bulk to a ration and may be used when other grains in the ration are heavy. Buckwheat is not a very palatable feed, nor is it equal to corn as a dairy feed. Dairymen believe that buckwheat produces a hard, white butterfat.

Corn.—Corn is grown on almost every dairy farm and should usually be included in the dairy ration. Not only is it very palatable, but moreover it supplies a large amount of total nutrients economically. It is low in protein and also in minerals; therefore, some high-protein feed must be used in order to supply these defi-

ciencies. Yellow corn is high in carotene; white corn is lacking in this material. It is best to feed corn ground as a meal. Some of the commercial corn meal is made from that part of the kernel which remains after the manufacture of cracked corn or table meal. It is then correctly called *corn feed meal.* It has about the same value as corn meal.

Sometimes whole ears are ground, making *corn and cob* meal. This is used in some dairy rations in place of corn meal and may be valuable in adding bulk when other bulky feeds are not available. The cob is high in pentosans and therefore can be utilized, to a certain extent, by the digestive system of the dairy cow. It has been found that when fed to steers about 2.5 pounds of cob were equal to 1 pound of corn meal.

When corn is purchased on the market it should be purchased on Federal grade which depends upon the amount of water it contains. According to the grade the water in corn must not exceed 14 per cent in No. 1, 15.5 per cent in No. 2, 17.5 per cent in No. 3, 20 per cent in No. 4, and 23 per cent in No. 5. Corn with more moisture than No. 2 will not keep well in storage.

Oats.—Oats are an excellent feed for dairy cattle and when not too high in price should be used in the dairy ration. They are considerably higher in food value than wheat bran. They are bulky, palatable, and fairly high in protein and mineral matter; and if they are home-grown the straw comes in handy for bedding. Oats vary greatly in composition and should be purchased on guaranteed analysis.

Rye.—Rye may be used in place of corn in a dairy ration. It is just about equal to corn in its food value, but it is not very palatable. There may be danger in feeding it when it is infected with ergot. When fed in large quantities it tends to produce butterfat with a hard body. It can be fed safely up to one-third of the grain ration.

Wheat.—When the price will permit, wheat may be substituted for corn in a dairy ration. It is a little higher than corn in feeding value and is quite palatable. Because of the small size and hardness of the kernels the wheat should be ground before being fed. Wheat, when fed alone, often forms a paste in the cow's mouth. In a great many sections the cost prohibits its use in the dairy ration.

Leguminous Seeds

Soy Beans.—Soy beans are becoming one of the important crops grown in this country. They are extremely high in protein of an exceptionally good quality. They are also high in fat and higher in total digestible nutrients than any of the cereals. They are not high in minerals or vitamins, and are not very palatable. They should be ground for dairy cows, which is often difficult on account of their sticky nature. However, when mixed with other grains they will grind easily. They are likely to turn rancid after grinding and so should not be ground too long before they are to be fed.

Field Peas.—Field peas sometimes are grown in the cooler parts of the United States as feed, but on account of their low yields are not extensively used. They are medium high in protein of only fair quality. They are low in calcium and vitamins, but are quite palatable and can be used satisfactorily.

Cow Peas.—Cow peas are not extensively used because the seed ripens unevenly. They can, however, be fed satisfactorily to dairy cattle. In composition and characteristics they are very similar to field peas.

By-products

In many industries there are by-products which can be used as cattle feed. Some of these by-products are high in quality and food value; others have but limited value.

Milling Industry

Buckwheat Middlings.—Buckwheat middlings is a by-product of the buckwheat-flour industry. It is fairly high in protein and, when it can be purchased at a reasonable price, makes a very good dairy feed. It should not be mixed with the hulls, which are worthless as a dairy feed.

Wheat Bran.—Wheat bran is one of the best of the milling products for feeding dairy cattle. It is palatable, bulky, and acts as a mild laxative. It also has a cooling effect, which makes it very useful as a feed for cows after calving. It is the highest of the

common feeds in its phosphorus content. It is desirable in any ration for dairy cows when the price is not too high. It is of especial value to cows just before and after calving. It is also a good feed for calves and heifers.

Wheat Middlings.—In the manufacture of flour the finer particles of bran, and some of the flour, are collected and sold as middlings or shorts. This is a very satisfactory feed for dairy cows, but it is more like ground corn in composition than bran. If middlings can be purchased cheaper than corn, they may be used as a substitute for corn in a ration. They are not as bulky nor as palatable as bran. In localities near steel mills, a product known as *palmo middlings* or *palmo midds* is found on the market. They are simply wheat middlings that have been used to remove the excess palm oil from the tin plate. They are similar in composition to wheat middlings but are higher in total digestible nutrients on account of the excess oil.

Oil Industry

Cottonseed Meal.—Cottonseed meal is the residue from the extraction of oil from the cotton seed, and is sometimes sold in cake form. Several different grades of this product are on the market. The highest grade is usually the cheapest and best to purchase. This feed is one of the most commonly used high-protein feeds. In general, it furnishes protein in the cheapest form of any of the concentrates. However, it is not very palatable and is low in calcium and vitamin A. It contains a poison known as "gossypol," which is thought to be injurious when fed in very large amounts. With dairy cattle, however, "cottonseed injury" seems to be caused by a lack of calcium and vitamin A. When good alfalfa hay or plenty of good quality hay of other kinds are fed, "cottonseed injury" will not occur.

Sometimes the hulls are ground and mixed with the feed and sold as *cottonseed feed*. This is not nearly as nutritious as the meal since the hulls are worthless as dairy feed.

Linseed Meal.—This high-protein feed is the residue left after the linseed oil has been extracted from the flax seed. In its manu-

facture two processes are used, one known as the old process and the other as the new. The old process consists in crushing the seeds, heating them to a high temperature, and removing the oil under high pressure. In the new process the seeds are treated in the same way except that the oil is extracted by being dissolved in naphtha instead of by pressure. The old process is the more commonly used in this country, although the new-process feed is sometimes found on the market. The difference in the methods of extracting the oil results in a slight difference in the composition of the residue from which the linseed meal is made. The new-process meal is slightly richer in protein but lower in energy value. These feeds are sometimes called "oil meal." They are more palatable than cottonseed meal, are laxative in effect, and seem to brighten the coats of the animals to which they are fed. When the price is right, they may be used advantageously in small quantities in the rations of dairy cows. They tend to produce a soft butter and hence are valuable in rations which would otherwise produce hard butter.

Soy-bean-oil Meal.—Soy-bean-oil meal is the residue left after the oil has been extracted from soy beans. It is very rich in protein of high quality, carrying more digestible protein than choice cottonseed meal. It is being used extensively in the dairy ration and has been giving excellent satisfaction. It is palatable and slightly laxative in effect. On account of the high quality of its protein, it is being used more each year.

Peanut Meal.—Peanut meal, a by-product of the manufacture of peanut oil, is becoming more important as a dairy feed. It varies considerably in composition, but first-grade peanut meal is very high in protein, is palatable, and has a slightly laxative effect upon the cow. It is not extensively used as a dairy feed but is very satisfactory when it is available.

Cocoanut Meal.—Cocoanut meal (copra-oil meal) is the residue from the manufacture of oil from the cocoanut, and is made by the two processes which have been described in connection with linseed meal. The old process is slightly lower in protein than the new one, but is higher in total nutrients. Cocoanut meal is higher in feeding value than wheat bran, but not as high as many of the other oil meals. It has a tendency to turn rancid in warm weather.

Brewing and Distilling

Brewers' Grains.—Brewers' grains are a residue from the brewing of barley in the making of beer and certain "soft" drinks. After the sugar is extracted the grains are dried and sold as dried brewers' grains. They are fairly bulky and, being medium-high in protein, are often used to an advantage. They are, however, low in digestible nutrients, high in crude fiber, and not very palatable. If the brewery is near by, many dairymen secure them wet. In this form they make a very satisfactory feed, but unless care is taken to have the feed boxes tight, the liquid will run through and ferment, creating an undesirable odor in the stable. When the grains are given proper care and the feed boxes kept clean, the wet grains can be fed without difficulty to dairy cows. They are often classified as a high-protein silage, and can be fed in place of corn silage.

Distillers' Grains.—Distillers' grains are by-products of the manufacture of alcohol from corn and rye. The distillers' grain from corn is much superior to that from rye. Corn distillers' grain is slightly more palatable than brewers' grain. It is superior to brewers' grains in protein and total digestible nutrients. Distillers' grains are sometimes fed wet, and practically all that has been said of the wet brewers' grains may be applied to the wet distillers' grains.

Starch Industry

Gluten Meal and Gluten Feed.—Gluten meal and gluten feed are by-products in the manufacture of starch and glucose. The gluten of corn, separated from the starch, is dried and sold as *gluten meal*; but when mixed with the corn bran it is known as *gluten feed.* The meal is therefore richer in protein and total digestible nutrients than the feed, but not so rich in calcium or vitamin A. The protein is not of very high quality, and hence this feed should be given with other feeds which will make good this deficiency. Both are satisfactory when they can be purchased at a price that makes them cheap enough to include in the ration. The meal is heavy and should be mixed with some more bulky feed. Neither of them is as palatable as some of the other feeds. As their protein content varies considerably, they should always be purchased on guaranteed analysis.

Sugar Industry

Dried Beet Pulp.—Beet pulp is the residue left after the sugar has been extracted from the sugar beet. It is very high in carbohydrates but low in protein. When silage or other succulent feeds are not available, dried beet pulp soaked with about three times its weight in water for about twelve hours before feeding makes an excellent substitute. When the cows are given free access to water, however, equally good results are obtained if the beet pulp is fed dry. It is very palatable and has a very good physiological effect upon the cow. Because of its bulky nature dried beet pulp is especially valuable in feeding cows for heavy production.

Molasses.—Molasses is a by-product of the manufacture of sugar from both beets and cane. A crude syrup is produced that is often used in feeding dairy cows. The molasses from cane is known as black strap. These products are essentially energy feeds as they are very low in protein. Molasses is quite laxative and should not be fed in a quantity to exceed 2 or 3 pounds daily for each animal. The customary way of feeding it on the farm is to dilute the molasses with water and sprinkle it over the feed. It is commonly found in many of the commercial mixed feeds. Molasses is often used to mix with feeds in order to lend palatability to them. It can be purchased dry and mixed with the feed at the time of mixing.

Hominy Grit Industry

Hominy Feed.—In the manufacture of hominy grits from corn, a by-product known as hominy feed is obtained. It has practically the same protein and carbohydrate content as corn, and may be used as a substitute for it. Practically the same things can be said of it as of corn for the feeding of dairy cows, although it is a little more bulky since it contains considerable amounts of corn bran. When it can be purchased cheaply as corn meal it may well be used in the ration.

Oat-meal Industry

Oat-mill Feed.—Oat feed is a by-product in the manufacture of oat meal. The oat grain when removed from the hull leaves a tip attached to the hull. This, together with the hull, is ground

into a feed which is very high in fiber but low in protein and total digestible nutrients. It is often used as a substitute for roughage, but its analysis is not much higher than that of oat straw. When fed for a concentrate it must be supplemented with some high-protein feed. Sometimes it is mixed with molasses to make it more palatable.

Packing Plant and Fishing Industries

Tankage.—Tankage is a by-product of the packing plant. It is a high-protein feed of animal origin and is being used considerably of late for dairy cattle. It is high in protein of an excellent quality, and in calcium and phosphorus. It is not very palatable to dairy cattle, but they soon learn to eat it if it is kept fresh. When fed in limited amounts it does not seem to impart undesirable flavors to the milk.

Blood Meal and Flour.—Blood collected at the packing plant is dried and sold as blood meal. It is a very high-protein feed, containing as much as 80 per cent protein, but it is low in calcium and phosphorus. It is not very palatable. A special process in which the blood is dried at a somewhat lower temperature has been used in the manufacture of a product known as a *soluble blood flour*, which makes an excellent feed for calves. It is more palatable and more digestible than the ordinary blood meal. It seems to have the power of keeping the digestive tract of a young calf free from disease.

Fish Meal.—Fish meal is made either from the entire fish, like the menhaden fish meal produced in eastern United States, or from the damaged fish and fish heads, as is done with the cod, sardine, salmon, and other fish of various regions. Fish meal is a high-protein feed and is rich in calcium and phosphorus. The protein is of high quality. When vacuum dried, it seems to be more digestible and contains more vitamins A, D, and G. It can be used for dairy cattle satisfactorily, although it should not be fed in too large amounts as it may give the milk a fish flavor. Many cows do not like it but usually will eat it mixed with other feeds. It makes a good protein supplement for calves, on account of the high quality of its protein.

Ready-mixed Feeds

A large number of ready-mixed feeds sold under special trade names are now on the market. They have the advantage of supplying the necessary variety to the ration and, being ready mixed, they save the labor of mixing. In the past these ready-mixed feeds were not looked upon with favor because many of them were sold simply as a means of disposing of some inferior products. More recently laws have been passed requiring the labeling of each sack with a guaranteed analysis. At the present time many excellent ready-mixed feeds may be purchased. Recently the *open-formula feed* has been put on the market. These open-formula feeds have the advantage that they show on the sacks the ingredients used in the ration and the amount of each. They have been gaining in popularity very rapidly.

Ready-mixed feeds are of especial value to the dairyman who uses only a small amount of feed or who is so located that it is impossible for him to secure readily a variety of feeds for home mixing. The buyer should always pay close attention to the guaranteed analysis, so that he may get his protein and total nutrients as cheaply as possible. His decision as to the use of ready-mixed feeds should depend largely upon the relative price. If the dairyman, however, has corn, barley, or oats on his farm, and needs a high-protein feed to balance these, he can usually purchase his protein cheaper in the form of cottonseed meal or gluten feed. It is always best to figure the cost of a pound of protein of each feed before purchasing, and in that way be sure of purchasing the most economical ration.

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LECTURE VII

DESIRABLE CHARACTERISTICS OF A RATION

IN order that the feeds may be combined in such a way that the best results are obtained, one must not only be familiar with the characteristics of the individual feeds, but must also know what factors enter into the make-up of a desirable ration. A ration for a dairy cow should contain a liberal supply of net energy or total digestible nutrients, sufficient protein of high quality, sufficient fat, and an adequate supply of minerals and vitamins. The ration also should be palatable, have a good physiological effect on the cow, and under normal conditions should have some bulk and variety. It should also be low in cost as regards the nutrients it contains.

WHAT BECOMES OF A COW'S FEED?

Milk, as has already been pointed out, contains the same compounds as the cow's feed, but in a different form. Figure 11 shows how the elements unite into compounds to form the feed out of which animals manufacture milk and satisfy their bodily needs. This figure shows that the dairy cow produces her milk entirely from the feed and water which she consumes, and that unless she receives sufficient of the right kinds of feed she cannot be expected to produce milk.

SUMMER CONDITIONS THROUGHOUT THE YEAR

In the making of a dairy ration, it should be the aim to imitate as nearly as possible the feed conditions of early summer. Every dairyman knows that the period of highest and most economical milk production is during the early summer months. This fact is not hard to explain. Early summer pasture provides for the dairy cow an abundance of palatable feed which is succulent in nature.

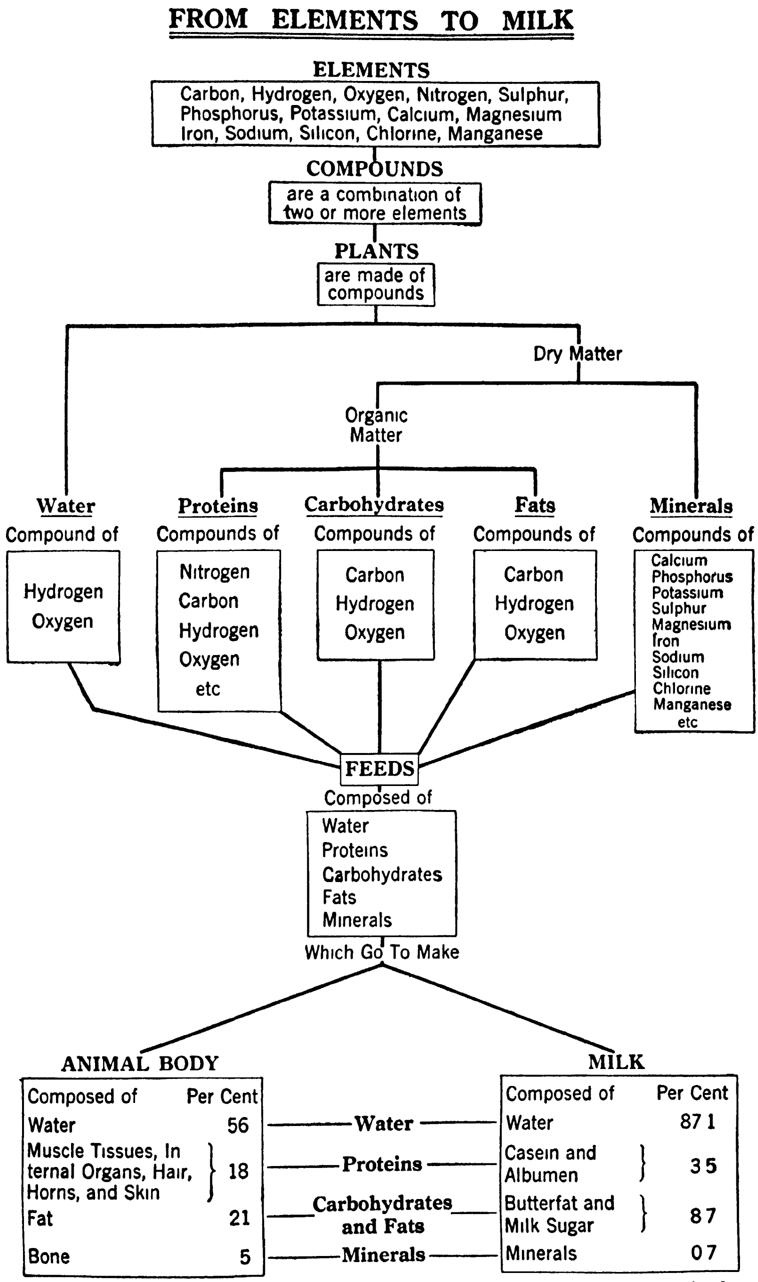

FIG. 11.—Chart showing interrelation of common component elements of plant and animal life which go to make up feed and finally milk

Having sufficient bulk and variety, it produces a good physiological effect upon the cow. Pasture also contains plenty of minerals and is cheap.

Right Amount of Feed

An abundance of feed is the first essential in feeding cows for profit. The primitive cow had only to care for herself and to feed her calf for a few months. After freshening in the spring of the year, she could develop the calf and dry off in the fall, and her labors were practically done. In these days the cow is looked upon, especially in the best dairy sections, simply as a factory, and, as in any other factory, the cheapest production is possible only when the plant is being run nearly to its full capacity.

A cow needs her food mainly for two purposes, namely, for the maintenance of her body and for the production of milk, although at times she may need it to grow a fetus or to put on weight. Young animals also need it for growth. The feed requirement for the maintenance of the body is the amount necessary to keep the body in running order, that is, to perform such functions as pumping blood, breathing, chewing and digesting food, and making body repairs. It has been shown that certain rather definite amounts of protein and energy are required for body maintenance, the amount depending upon the size of the cow. Figure 12 illustrates how the feed consumed by a dairy cow is utilized when she is given different amounts.

Figure 12 refers to a cow whose body weight is 1000 pounds and whose maximum production is 20 pounds of 4 per cent milk. It will be noted that the maintenance requirement remains constant regardless of the production. The feed requirement for maintenance is determined entirely by the size of the cow, irrespective of breed, age, or any other factor. It is true that a good dairy cow will draw on the reserve of her body to produce milk for a limited length of time. Nevertheless, the factor for maintenance remains constant and this reserve must eventually be replaced from the feed, otherwise the cow will become emaciated and her production will be diminished.

Figure 12 also shows that it is poor economy to feed sparingly. The feed required for maintenance remains the same, and unless

WHAT BECOMES OF A COW'S FEED

When Fed too Much

Maintenance	Milk Production	Gain in Weight
1000-pound cow	20 pounds of 4 per cent milk	Stored up

When Fed Just Enough

Maintenance	Milk Production
1000-pound cow	20 pounds of 4 per cent milk

When Fed too Little

Maintenance	Milk Production
1000-pound cow	10 pounds of 4 per cent milk

FIG. 12.—Chart showing how the dairy cow utilizes her feed.

the cow is fed enough for liberal milk production in addition to the requirement for maintenance, the proportion of food which goes to make the milk is less than it should be. A cow should be fed practically to the limit of her milk-producing capacity. Aside from her feed and care, the limiting factor is the cow's inherent capacity for milk production. The 1000-pound cow producing 20 pounds of 4 per cent milk used approximately 50 per cent of the feed for maintenance and 50 per cent for production. When, however, this cow produced only 10 pounds of 4 per cent milk, largely because of lack of feed, approximately 66 per cent of the feed was required for maintenance, leaving only 33 per cent for milk production.

Overfeeding.—Most dairymen do not feed enough, but there are some who, being good feeders, and having cows in their herd which do not have the inherent ability to produce heavily, overfeed them. There is no economy in feeding a dairy cow more than she will return in the milk she produces. This is illustrated in Figure 12 where the cow still produces 20 pounds of milk and uses the remainder for gain in weight. Unless the cow is in poor condition,

the gain in weight is of no value as far as milk production is concerned, unless it is used as a reserve which may be drawn upon at some future time.

PROTEIN

A dairy cow must be given an adequate amount of protein for body repair and for milk production since she cannot synthesize protein out of non-protein material, such as carbohydrates and fats. The amount of protein required by a dairy cow depends upon her size and upon the amount of milk that she is producing. It also depends upon the quality of the protein. Some of the proteins are lacking in certain amino acids. It is sometimes necessary to feed more of these proteins than the minimum requirements in order to get sufficient of certain amino acids. The cow really requires a definite amount of the essential amino acids rather than a definite amount of protein.

Since protein feeds are usually higher in price than carbohydrate feeds, the amount fed is kept to the minimum. Sometimes, however, the conditions are such that protein-rich feeds may be cheaper than carbohydrate-rich feeds, and then it may be profitable to feed a larger amount of protein than is actually necessary. This of course throws a heavy load on the liver and kidney in getting rid of the excess nitrogen but it has been shown that heavy feeding of protein is not harmful to dairy cows, provided they are given an adequate ration in other essentials. The excess protein is broken down and the nitrogen excreted, and the remaining portion can be used for energy.

The amount of protein required under normal conditions has been worked out and is given in the requirements for maintenance and milk production in the next lecture. The amount needed for growth has also been determined and is given in Lecture XXI.

CARBOHYDRATES

The carbohydrates usually constitute the main portion of the dairy ration and are used largely for the production of work. The amount required depends not only upon the size of the animal but also upon the amount of physical or productive work that the animal is doing. As the amount of milk that a dairy cow produces in-

creases, the amount of carbohydrates needed also increases. The amount required also depends upon the amount of protein and fat included in the ration. These two compounds can be broken down and utilized for the production of work. Since this is true, the terms net energy and total digestible nutrients are generally used since they include the productive value of all three of these compounds. The carbohydrates are ordinarily the cheaper forms of feed and should be fed in large amounts, although not in such amounts that the dairy cow will not receive sufficient protein.

Fats

A certain amount of fat is always found in the common feeds. These fats are used much like carbohydrates for the production of work, although they are so much more concentrated that they are about two and one-quarter times more efficient pound for pound than the carbohydrates. Carbohydrates, however, can be converted into fats; and so an animal could get along with a small amount of fat provided the ration is adequate in other essentials. Recent experiments [1] have shown that for ordinary feeding a level of 4 per cent of fat in the grain mixture which is fed at the rate of 1 pound for every 3 to 3½ pounds of milk along with an adequate amount of hay and corn silage of good quality may be considered substantially adequate for milk production. A higher level is not justified if it increases the cost of the ration per unit of total digestible nutrients.

Minerals

It has been demonstrated that animals fed on rations practically free of minerals will die even sooner than animals deprived of all feeds. The necessity of supplying minerals has already been demonstrated. The minerals most likely to be lacking in a ration are calcium, phosphorus, sodium, chlorine, iodine, iron, and copper. All these are contained in varying amounts in the common feeds, but sometimes it may be of advantage to supply additional quantities.

Common Salt.—The sodium and chlorine are contained in common salt (NaCl), which should be supplied at all times. All her-

[1] Cornell Exp. Sta. Buls. 543 and 593.

bivorous animals require a large amount of salt, but carnivorous animals do not require any more salt than they obtain in their feed. Bunge[1] states that chlorine is the essential element supplied by salt. He says that it unites with the potassium which is found in large amounts in feeding stuffs, and thus helps expel it from the body.

One of the common ways of supplying the needed salt is to keep it so that the animals will have free access to it and will take what they require. It may also be mixed with the grain ration in the proportion of 1 to 1¼ pounds of salt for each 100 pounds of grain mixture. When this is done the cows should also be given free access to salt so that they may secure more if necessary. Salting at intervals of several days or weeks is not to be recommended. The actual amount needed depends on the size of the animal and the amount of milk she is producing. Babcock[2] concluded that dairy cows should be given about ¾ ounce per day for each 1000 pounds of live weight and about ⅗ ounce in addition for each 20 pounds of milk produced.

Calcium and Phosphorus.—The importance of supplying calcium and phosphorus in the ration, in addition to the amounts found in ordinary feeds, has perhaps been overestimated. Under ordinary conditions, if the dairy cows are given plenty of legume hay in winter and pasture in summer and are fed a good grain ration, there is little to be feared from a lack of these elements. Legume hay is especially rich in calcium; and the concentrates, such as wheat bran and cottonseed meal, are rich in phosphorus. However, if cows show abnormal appetites, such as a craving for wood, bones, or dirt, this is a strong indication that the ration is lacking in one or both of these elements. Such a condition is more likely to occur with the heavy-producing cows or when the roughage is timothy or other non-legumes.

There are two times when minerals are most likely to be lacking in the ration of the dairy animal, during heavy lactation and during growth. It should be understood, however, that a cow may produce milk for some time, even for several months, without having sufficient minerals in her feed. This is possible because she can draw on her reserve supply—the calcium and phosphorus in her bones.

[1] Jour. Dairy Sci. 1:487.
[2] 22nd An. Rep., Wisc. Exp. Sta.

If she is allowed to draw on this reserve she should be given a chance at some time to replace this reserve. Restoring minerals in the body of cows fed rations low in minerals is done only when the cow is dry or nearly so, and best when she is on grass. This shows the necessity of a dry period for such animals. Forbes [1] found that the calcium metabolism of the milch cow, regardless of how she is fed, is characterized by a rapid loss from the body during the early part of the lactation period, changing to retention late in the lactation; by continued retention during the dry period; and by the most rapid storage at the end of the period of gestation. He attributes the loss during the first part of the lactation to the impulse to secrete milk, as accentuated by selective breeding, and to a limited ability to assimilate calcium. Huffman,[2] however, has shown that cows on a good ration of alfalfa hay are able to maintain a positive mineral balance even though they are producing as much as 70 pounds of milk per day. Meigs [3] found that the feeding of additional phosphorus to cows during the dry period seemed to have a beneficial effect upon their production during the subsequent lactation period.

It is known that vitamin D is associated with calcium and phosphorus assimilation. It has been shown also that the ultra-violet rays from the sun or other sources help with this process. Vitamin D is found most abundantly in green grasses and in well-cured legume hay.

Calcium-Phosphorus Ratio.—Not only should animals be fed sufficient calcium and phosphorus, but a proper ratio should be maintained between the two minerals. The proper proportion for dairy cattle is not fully known; a ratio of 1 : 1 or 2 : 1 is probably not far from ideal, although if plenty of vitamin D is present a wider ratio can be used without harmful results.

Form in Which to Feed Calcium and Phosphorus.—When it is found advisable to supply calcium or phosphorus in addition to that supplied by the feed, it is best to feed some bone meal of the kind especially prepared for livestock feeding. This contains both calcium and phosphorus in the proportion used in the body. It is sold under the name of "raw bone meal for feeding purposes."

[1] Jour. Biol. Chem. 52 : 28.
[2] Jour. Dairy Sci. 13 : 432.
[3] U.S.D.A. Bul. 495.

"Spent bone black" serves the same purpose as bone meal and sometimes can be purchased at a lower price. Finely ground limestone, marl, or wood ashes may also be used if there is sufficient phosphorus in the ration, for these supply only the calcium. Only limestone that is low in magnesium should be used. Rock phosphate has proved unsatisfactory as a feed because of the detrimental effect of the excessive fluorine contained in it. The fluorine affects the bones and teeth of the animals. Many commercial mineral compounds are on the market, but no better results can be expected from them than from bone meal or a mixture of bone meal and limestone. The price of commercial preparations is usually much higher than that of bone meal.

The bone meal, ground limestone, or wood ashes can be fed like salt by allowing free access to it, or it may be added to the grain ration at the rate of about 2 pounds to each 100 pounds of the ration.

The best way to supply minerals is through the feed. Some feeds are low in calcium, and others in phosphorus. In general, the roughages are low in phosphorus, and the concentrates low in calcium. The following table shows the feeds that are rich, medium, and poor in these elements: [1]

Calcium Poor	*Calcium Medium*	*Calcium Rich*
Cereal grains	Dried beet pulp	Legume hays
Corn	Corn silage	Alfalfa
Wheat	Corn stover	Red clover
Oats	Linseed meal	Soy bean
Rye	Cottonseed meal	Tankage
Cereal grain by-products	Corn gluten	Dried milk products
Legume seeds		
Roots		
Timothy hay		
Straws		

Phosphorus Poor	*Phosphorus Medium*	*Phosphorus Rich*
Beet pulp	Cereal grains	Wheat bran
Polished rice	Corn	Wheat germ
Red-clover hay	Wheat	Wheat middlings
Timothy hay	Oats	Cottonseed meal
Millet	Rye	Legume seeds
Straws	Alfalfa hay	Linseed meal
	Corn stover	Tankage
	Corn silage	Dried milk products
	Sweet clover	

[1] Minn. Spec. Bul. 94.

Iodine.—In certain sections of the country, cattle suffer from goiter, or "big neck." This is caused by a lack of iodine in the ration. It appears in calves as a swelling of the neck at birth. Sometimes it may be so severe that death occurs, but usually the calf recovers although the swelling may remain until she matures.

When this trouble is experienced it is well to take the proper precautions and treat all pregnant animals in the herd. One method of administration is to give potassium iodide or sodium iodide (a cheaper source) in the feed. A solution is made by dissolving 1 ounce of either substance in 1 gallon of water. One tablespoonful of this solution on the grain ration constitutes the daily dose. Iodized salt containing 0.001 part potassium or sodium iodide can be fed with good results.

Iron and Copper.—Although the amount of iron and copper found in the body is very small, recent investigators[1] have found that an ample supply of iron and a small amount of copper are necessary for the formation of hemoglobin in the blood. Without these elements, nutritional anemia results. Ordinarily there is no lack of these elements in the ration of dairy cattle, although in certain sandy areas the forage is so low in these elements that cattle suffer from anemia. The trouble may be prevented by giving the cattle access to a mineral mixture consisting of 100 pounds of common salt, 25 pounds of red oxide of iron, and 1 pound of finely ground copper sulfate.

Calves fed on rations consisting of milk as an exclusive diet will suffer from anemia. When good roughage is fed such trouble is avoided.

VITAMINS

The discovery that vitamins play an important part in nutrition was made comparatively recently. These organic compounds have a very profound effect upon dairy farming by increasing the efficiency of production and the prevention of nutritional diseases. The necessity for vitamins in the ration of the dairy animal is important for the benefit not only to the animal itself but also to the milk which the cow produces. In most of the study of feeds the needs of the animal was the only consideration, but in respect to vitamin feeding it is necessary to consider also the effect on the vitamin content of

[1] Fla. Exp. Sta. Bul. 231.

the milk produced. This milk is used as a human food, and it is important that it carry an adequate supply of vitamins.

Up to the present time at least six different vitamins have been discovered; they are known as vitamins A, B, C, D, E, and G. Several others have also been suggested but until they have been more thoroughly studied very little can be said about them.

Vitamin A.—Vitamin A is one of the most important vitamins to the dairyman. It is necessary for growth, for maintenance of the mature animal, for reproduction, and for milk production. It is an important part of milk, where it is found associated with the butterfat. Cows fed rations lacking in vitamin A will produce milk lacking in this vitamin. Animals have the ability to store a little vitamin A in their liver and other tissue, but this amount is quite limited.

Plants have very little or no vitamin A in their tissue. It is there held as carotene, which is known as the precursor of vitamin A. Carotene is widely distributed in plants but is more abundant in those of green, yellow, or orange color. The feeds increase in their potency of carotene as the color intensifies. The dairy cow cannot synthesize vitamin A in her body, but it must be supplied to her in her feed either as vitamin A or as its precursor, carotene. The conversion of carotene into vitamin A in the cow's body is probably a simple chemical change which results in the splitting of the carotene molecule and the addition of one molecule of water to each half.

$$\underset{\text{Carotene}}{C_{40}H_{56}} + \underset{\text{water}}{2H_2O} \longleftrightarrow \underset{\text{Vitamine A}}{2C_{20}H_{30}O}$$

This change probably takes place in the liver, which acts as a storehouse of carotene and also serves to regulate the amount of vitamin A to be transferred to other parts of the body. In milk production it may be secreted either as vitamin A or as carotene. As vitamin A is colorless, milk yellow in color contains the unchanged carotene.

The amount of vitamin A or carotene in the milk depends to a large extent upon the amount in the feed. A sufficiency is assured when the feed is green, as when the cows are on good pasture. Often the milk from cows on pasture will contain twice as much vitamin A as when they are barn fed. In the field curing of hay or other dry roughages a considerable portion of the carotene is

destroyed, especially if it is bleached either by the sun or rain. Hay cured with a green color is a very good source of vitamin A.

Corn silage varies considerably in its carotene content, depending upon its greenness when ensiled; if ensiled when green it may have as much carotene as well-cured alfalfa hay. The concentrates, with the exception of yellow corn and its by-products, are practically free of carotene. Even yellow corn is not a very good source of vitamin A as it contains only about one-tenth as much as well-cured alfalfa.

Cod-liver oil is sometimes fed to dairy calves to add this vitamin. The United States Department of Agriculture states that 20 to 25 cc. of animal-feeding cod-liver oil or 15 mg. of carotene roughly equals the vitamin requirement of growing calves during the milk-feeding age.

Vitamin B.—Most of the feeds which are fed to dairy cows are fairly rich in vitamin B so that they seldom, if ever, suffer from the lack of this dietary factor. The cereal grains, green forage, silages, well-cured hay, and other forages are all rich in vitamin B. It has been shown [1] also that vitamin B can be formed in the paunch of the dairy cow by the action of enzymes produced by certain bacteria. Dairy cows therefore seldom suffer from the lack of this vitamin.

Vitamin C (Ascorbic Acid).—The dairy cow does not seem to be affected by the lack of vitamin C in her ration. She probably is able to manufacture her own supply as the amount in the milk is not greatly affected by the feed consumed. In one experiment [2] three cows were stall fed, each with 150 pounds of green rye, which was estimated to contain as much vitamin C as 20 gallons of orange juice, but without results as to the amount of vitamin C in the milk. Green forage is especially rich in vitamin C, and corn silage may contain fairly large amounts. Sprouted seeds are also rich in it. Dried roughages and grains and other by-products are lacking in this vitamin.

Vitamin D.—Animals must have an adequate supply of vitamin D in order to assimilate and use the calcium and phosphorus in their feed. Without this vitamin young cattle will suffer with rickets

[1] Jour. Biol. Chem. 80: 231.

[2] Jour. Nut. 11: 1.

and older animals need it especially during pregnancy, so that sufficient calcium and phosphorus will be available for building the skeleton and other tissues of the fetus. During lactation it is also needed because of the large amount of calcium and phosphorus which goes into the milk.

Vitamin D is not found in many of our common feeds. Green forage, silages, and grains and their by-products are all low in this vitamin. Sun-cured hays may contain a limited amount as the result of the action of the sunlight on the hay.

Sunlight or other lights which contain the ultra-violet rays have the power of changing a compound known as ergosterol, and other related compounds, into vitamin D. Small amounts of these compounds occur in most of the common feeds. Cattle exposed to the sun's rays will not usually be lacking in this vitamin, for the ultra-violet rays from the sun, acting upon their bodies, produce sufficient vitamin D. During the season of the year when cows are housed, or when there is little or no sunshine, cattle may be lacking in this vitamin.

Milk from cows fed a normal ration will contain a small amount of vitamin D, but such milk is not an exceptionally good source of this vitamin. Many attempts have been made to increase the vitamin D content of milk by feeding materials rich in this vitamin. The feeding of irradiated yeast has so far given the best results. Feeding 10 ounces of this material per day to the cows results in a milk which is quite rich in vitamin D. Irradiation of the milk has also been successful in adding this vitamin to milk.

Vitamin E.—Vitamin E is necessary for successful reproduction in certain species of animals, but either the common feeds contain an ample supply of this vitamin or the dairy animal is able to manufacture her own supply or does not need the vitamin. It is abundant in the germ of cereal grains and other seeds, and is also found in green forage and well-cured hay. Very little is known concerning the effect of this vitamin on dairy cows, but it is doubtful that cows fed a good, balanced ration will lack this factor.

Vitamin G.—Vitamin G has never been found lacking in a dairy ration. Either the cow can manufacture her own supply or it is supplied in ample amounts in the common feeds. Milk is usually rich in this factor.

Palatability

In order to be palatable a feed must be pleasing in flavor so that the cow will like it. A cow will do her best when she relishes her feed. A ration may contain everything necessary for maximum production; yet, if it is not palatable, the cow may not consume enough of it to supply nutrients for her maximum production. One of the objects of feeding is to tempt the cow's appetite, thereby inducing her to eat up to the limit of her ability to produce milk.

Cows, like people, show individuality by different tastes and appetites. Certain feeds not eaten at all by some cows are relished by others. Cows can become accustomed to eating some feeds that do not at first appeal to them. It is known that palatability has little effect, if any, on digestibility. The advantage of the palatable feeds over the unpalatable ones is simply that the cow will consume a larger amount, and, as has been pointed out, the economy of production depends largely upon the amount of food the cow will eat above what is necessary for her maintenance. If unpalatable feeds are to be used, they should be mixed with palatable ones. Molasses is sometimes mixed with unpalatable feeds to give them the desired palatability.

Succulence

A succulent feed is one that contains the natural juices of green forage, similar to the natural juices of pasture grass. Although milk can be produced satisfactorily if a good legume hay is fed and if water is available to the cows at all times even without a succulent feed, nevertheless cows will usually consume more feed and keep in better physical condition when the ration is made succulent by including some form of green feeds or others high in moisture. This is especially true if low-quality roughage is being fed. Some of the common succulent feeds are green grasses, silage, and roots. Some form of succulence is usually necessary for economical milk production.

Bulk

A grain mixture is said to have bulk when a definite weight of it occupies a relatively large space. To illustrate: 100 pounds of

wheat bran occupies much more space than 100 pounds of corn meal; hence it is said to be more bulky or lighter.

Bulk is necessary in a dairy ration, but usually bulk is sufficient if the required amount of roughage is fed. Formerly, it was thought that it was necessary to have a certain amount of bulk in the grain ration, otherwise the feed would form in balls in the digestive tract, the digestive juices would not penetrate, and the cows would go off feed. Results of experiments [1] seem to indicate that the reason for such cows going off feed may not be a lack of bulk in the grain ration. It has been found that all the grain mixture passes directly to the rumen or reticulum and is there mixed with the content of the rumen so that all balls of feed are broken up very soon after going into the stomach. Bulk therefore appears to be unnecessary in the grain ration except possibly for high-producing cows that are being heavily fed. Wheat bran, ground oats, corn and cob meal, dried brewers' grain, alfalfa meal, and beet pulp are the more common bulky feeds. There is no harm in having a certain amount of bulk in the grain ration if the feeds are at hand or can be purchased so that the protein is no more expensive than that in other protein concentrates.

Variety

In compounding a grain ration so that it will have palatability, three or four grains are generally used for the sake of variety. It is a common belief that if a cow is kept on the same ration for a long period of time she will lose her appetite. This, however, is not necessarily true. If the ration contains variety and succulence and is palatable, the cows will do better without many changes.

For winter feeding two kinds of roughages are desirable; one a silage or some other succulent; and the other preferably a legume hay, although good results have been obtained by the feeding of a legume hay by itself. The grain ration for moderate-producing cows should contain at least two or three grains, or by-products, preferably from different plant sources. For heavy-producing cows, four or more different feeds should be supplied, from at least three or four different plant sources. Many feeders use as many as seven or more different feeds for high production.

[1] Jour. Agr. Res. 44: 789.

As was mentioned previously, proteins are made up of a large number of amino acids, some of which are essential for life and for maximum milk production. Often the proteins from one plant are deficient in some of these. For example, zein, which makes up more than one-half of the protein of the corn grain, is completely lacking in three amino acids and has a relatively small amount of three others. Corn-grain protein alone will not support life, but when supplemented with a small percentage of protein from the corn fodder it serves for the growth of calves. Furthermore, some feeds are deficient in certain minerals. The oat plant, for instance, does not contain enough calcium for proper growth and reproduction. For these reasons it is necessary to have a ration which represents several different plants. For example, a ration consisting of corn stover, corn silage, corn and cob meal, gluten feed, and wheat bran would represent only two plants; a ration consisting of alfalfa hay, corn silage, corn meal, ground oats, and linseed meal would represent four plants and for this reason should give better results. The protein of certain feeds, such as alfalfa hay, seems to be very complete and will support growth and milk production. Variety is not so important for moderate-producing animals, but with heavy producers it should be given consideration.

Effect on Health

Each feed has its own peculiar effect upon the animal body. The specific effects of all feeds are not known as yet, but certain effects of some of the feeds are established. Corn stover, for instance, is known to cause constipation, and wheat bran has a laxative effect. For these reasons neither of these feeds should be fed in large amounts unless some feeds that have the opposite effects are fed with them. Some of the roughages, such as silage, clover hay, and alfalfa hay, are laxative; some, such as timothy hay, oat straw, and corn stover, are constipating. When the roughages are constipating in effect, a grain mixture of a laxative nature must be fed if the dairy cow is to do her best. The bowels of a dairy cow should be in a slightly laxative condition if she is to make her best production.

Cheapness

The careful feeder will try to select cheap feeds, but in this he will not make the cost per ton the essential consideration. The important thing to be considered is the cost of 1 pound of digestible proteins and 1 pound of total digestible nutrients. It is well, from the point of view of economy, to make use of as many home-grown feeds as possible, and to purchase only what is necessary to balance them properly. If home-grown feeds are used the cost and labor of marketing is eliminated.

Amount to Feed

Feeders should know the amount of grain and roughage to give their animals. The digestive system of the dairy cow is especially adapted to consume large amounts of roughages, and she should be given plenty of bulky feeds. The proportion of grain to roughage will depend largely upon the amount of milk the cow is giving. Heavy milkers will consume much more grain in proportion to roughage than those that are not producing so heavily. Usually, the poor to medium producers receive only about 25 to 30 per cent from their concentrates, while a good producer will receive from 40 to 50 per cent from her concentrates. Very high producers may be fed as high as 70 to 80 per cent of their feed in their concentrates.

The following general rules are given as a guide for the beginner in feeding, to help him to use proper proportions of grain and roughages in his ration:

Feed all the roughage that the cows will eat up clean. This will usually be about 1 pound of hay and 3 pounds of silage to 100 pounds of live weight per day. With no silage, as much as 2 pounds of hay may be fed. When beet pulp is used, feed about 4 to 8 pounds of dry pulp. If preferred it may be soaked in three times its weight in water. Beets may be fed up to 60 or 80 pounds.

The grain mixture should be fed in proportion to the milk yield. As a general rule, with a good roughage, high-testing cows are fed 1 pound of grain to each 2½ to 3 pounds of milk, and low-testing cows 1 pound of grain to each 3 to 3½ pounds of milk. With poor roughage, the grain allowance should be increased. A more definite procedure is given in Table XXI in Lecture X.

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LECTURE VIII

THE DEVELOPMENT OF FEEDING STANDARDS

Feeding Standards

The science of feeding is based upon certain requirements for maintenance and milk production. These requirements are known as feeding standards. They have developed with the progress of other sciences. The first standard was based upon simple feeding trials in which one feed was substituted for another and the results compared. A standard obtained in this way is said to be of the comparative type.

With the beginning of food analyses, a new standard was made, based upon food constituents. It was soon found that the food constituents were not equally digestible. This led to digestion trials, and the standard then proposed was based upon digestible constituents. Such standards are said to be of the digestible-nutrient type. The German respiration apparatus and Armsby's respiration calorimeter have given us what is known as the energy standard or the production-value type.

A feeding standard, then, is simply the food requirement for maintenance and milk production. Of the many standards proposed, only four are in wide use in the United States at the present time. These are the Armsby, the Haecker, the Savage, and the Morrison systems.

Comparative Type

Thaer's Work.—The German scientist Thaer in the year 1810 suggested a method of comparing the different feeds. He used meadow hay as a unit and based the value of the rest of the feeding stuffs on its value. He found, for instance, that only 91 pounds of alfalfa hay were necessary to equal 100 pounds of meadow hay in feeding value, and that 200 pounds of potatoes were required to replace 100 pounds of meadow hay. He never formulated a definite

standard but simply gave a comparison of the feeding stuffs. However, a system very similar to this is now used extensively in the Scandinavian countries.

Scandinavian Feeding System.—The Scandinavian feeding standard is more valuable than that of Thaer in that it is the result of observations on thousands of cows, extending over a great number of years. The quantity of milk was also taken into consideration. For some years [1] a number of dairy farms in Denmark, Sweden, and parts of Norway were under the direct observation of the respective governments. Complete records were kept of the food consumed and of the quantity of milk produced, and in 1884 Professor Fjord formulated the Scandinavian feeding standard. Because of its simplicity this standard met with considerable favor in this country for some time. In the Scandinavian standard only one factor, namely, the feed units, was taken into account; in the Wolff-Lehmann and older Haecker standards protein, carbohydrates, and fat were considered. However, since most of the standards now commonly used have only two factors to be considered, and since the type of feed raised in this country is quite different from that grown in northern Europe, so that it has been found necessary to include digestible crude protein in addition to the feed unit, the use of this standard has gradually decreased until at present it is employed very little in the United States.

The term feed unit is the basis for the standard. One pound of the common grains, such as corn, barley, wheat, etc., is given a value of 1 unit and the value of all the other feeds is based upon this. This is similar to the method of Thaer, who based his comparison on 100 pounds of meadow hay. According to the Scandinavian standard, one feed unit is required for each 150 pounds of body weight, and one additional unit for every 3 pounds of milk produced. In addition to the feed units, the ration should also contain 0.065 pound of digestible protein for each 100 pounds of live weight and 0.05 pound of digestible protein for each pound of milk produced.

The general composition of the Danish feeds is somewhat different from that of the feeds of this country as a number of those common in this country are not found in Denmark. Corn silage,

[1] Wisc. Exp. Sta., Circ. 37.

for example, is scarcely used at all in Denmark. Rabild, of the United States Department of Agriculture, therefore worked out the following table showing the feed units in a number of our most common dairy feeds.

The feed units in this table are based upon average analyses of feeds and are subject to revision. A somewhat similar table presented by Woll is given as Table B in the appendix.

TABLE X

SCANDINAVIAN FEEDING STANDARD

American Feed Unit

	Pounds Required for One American Unit	Range of Variations
Rye, ground	0.95	0.95– 1.05
Oats, ground	1.00	1.00– 1.20
Wheat middlings	1.09	
Wheat bran	1.28	1.18– 1.38
Barley, ground	0.95	0.95– 1.05
Dent corn	0.97	0.87– 1.07
Corn and cob meal	1.20	
Gluten feed	0.88	0.73– 1.13
Cottonseed meal	0.76	0.76– 0.86
Linseed meal	0.85	0.75– 0.95
Dried beet pulp	1.17	
Malt sprouts	1.03	1.03– 1.33
Dried brewers' grains	1.11	
Potatoes	6.00	5.00– 7.00
Sugar beets	8.15	7.15– 9.15
Rutabagas	9.70	8.00–10.00
Mangel wurzels	12.10	11.10–13.10
Alfalfa hay	1.92	1.72– 2.22
Alfalfa, green	6.47	4.47– 8.47
Alfalfa meal	1.64	1.64– 2.64
Red clover hay	2.32	2.12– 2.62
Oat straw	4.35	3.85– 4.85
Fodder corn, green	8.06	6.00–10.00
Corn stover	2.73	2.70– 4.70
Corn silage	6.62	5.62– 7.62

It will be noted that the values of 1 pound of various grains, such as barley, oats, or corn, are given as almost equal. These feed units are not, therefore, entirely accurate, because they are based

on comparison and do not give the true energy value. Feeds rich in protein are given a higher value than those low in protein but containing an equal amount of net energy. For example, gluten feed has a feed-unit value of 0.88; this is lower than that of corn, which is 0.97, but according to the net energy table corn contains more net energy than the gluten feed. The greatest merit of the Danish system is its simplicity. The feed-units value of the common feeds can be remembered, and after a little practice a practical ration can be figured without referring to tables.

Digestible-nutrient System

Grouven's Feeding Standard.—In 1859,[1] about fifty years after Thaer published his standard, Grouven, another German experimenter, proposed a feeding standard based upon the crude protein, carbohydrates, and fats contained in the feeds. His standard required that a cow weighing 1000 pounds be fed 28.7 pounds of dry matter containing 2.76 pounds of crude protein, 0.86 pound of crude fat, and 14.55 pounds of crude carbohydrates.

Very soon after this standard was proposed, Henneberg and Stohmann carried on digestion trials and found that the total nutrients contained in a feed did not form an accurate guide to its value. The proportions of the digestible parts varied with the different feeds, hence digestible nutrients would be more valuable.

Wolff's Feeding Standard.—Dr. Emil von Wolff made similar studies and in the year 1864 proposed a standard based upon the digestible protein, digestible carbohydrates, and digestible fat. His standard for dairy cows weighing 1000 pounds is as follows: Dry matter, 24.5 pounds, containing 2.5 pounds of digestible protein, 12.5 pounds of digestible carbohydrates, and 0.4 pound of digestible fat. This has a nutritive ratio of 1 to 5.4. The nutritive ratio is the proportion of protein to carbohydrates plus $2\frac{1}{4}$ times the fat. This standard, although a great improvement over the others, was deficient in that it did not take into consideration the quantity and quality of the milk produced.

Wolff-Lehmann Feeding Standard.—The Wolff Standard was used until 1896 when it was modified by Dr. C. Lehmann of Berlin,

[1] Cornell Exp. Sta. Bul. 323.

after which it was called the Wolff-Lehmann Standard. Lehmann took into account the quantity of milk. This was an improvement over the Wolff Standard, although Lehmann failed to take into account the quality of the milk. The Wolff-Lehmann Standard is given in Table XI.

TABLE XI

WOLFF-LEHMANN STANDARD FOR DAIRY COWS

Daily Yield of Milk	Dry Matter, lb.	Digestible Nutrients for 1000-Pound Cow				
		Lb. Crude Protein	Lb. Carbohydrates	Lb. Fat	Sum of Nutrients	Nutritive Ratio
11.0	25	1.6	10	0.3	11.9	1 to 6.7
16.6	27	2.0	11	0.4	13.4	1 to 6.0
22.0	29	2.5	13	0.5	16.0	1 to 5.7
27.5	32	3.3	13	0.8	17.1	1 to 4.5
For maintenance	18	0.7	8	0.1	8.8	1 to 11.8

This standard was used for a great many years, and at the present time various modifications of it are employed very extensively in the United States. The most common modifications are the Haecker, the Morrison, and the Savage feeding standards.

Haecker's Feeding Standard.—The improvement of the feeding standard was a gradual one. Up to the end of the nineteenth century, one important consideration, namely, that of the quality of the milk, had not been considered. It was Haecker [1] of Minnesota who proposed a standard which not only included the quantity of the milk but also the quality. He was also the first to separate the requirements for maintenance from the requirements for production. Whereas the German investigators worked with a few animals and controlled their experiments very carefully, Haecker worked with a large number over a long period of time under normal conditions. He put out three sets of figures, each a little higher than the one before.

[1] Minn. Exp. Sta. Bul. 130.

With this system the needs of a cow of any size, producing any quantity or quality of milk, can be easily computed. Haecker expressed the value of the feeds under three heads—digestible crude protein, carbohydrates, and fat. Later, however, they were grouped under two heads,[1] namely, digestible crude protein and total digestible nutrients. Tables XII and XIII show the amount of nutrients required for maintenance and milk production, expressed in single terms and also as total nutrients.

TABLE XII

DAILY MAINTENANCE REQUIREMENTS FOR DAIRY COWS BY HAECKER STANDARD

Weight	Digestible Crude Protein, lb.	Carbohydrates, lb.	Fat, lb.	Total Digestible Nutrients, lb.
800	0.560	5.60	0.08	6.340
850	0.595	5.95	0.08	6.725
900	0.630	6.30	0.09	7.132
950	0.665	6.65	0.09	7.517
1000	0.700	7.00	0.10	7.925
1050	0.735	7.35	0.10	8.310
1100	0.770	7.70	0.11	8.717
1150	0.805	8.05	0.11	9.102
1200	0.840	8.40	0.12	9.500
1250	0.875	8.75	0.12	9.895
1300	0.910	9.10	0.13	10.302
1350	0.945	9.45	0.13	10.689
1400	0.980	9.80	0.14	11.095
1450	1.015	10.15	0.14	11.480
1500	1.050	10.50	0.15	11.887

Savage Feeding Standard.—Savage, of the Cornell Experiment Station,[2] after many trials, came to the conclusion that the Haecker standard was too low, especially in protein. He maintained that the nutritive ratio should not be wider than 1 to 6. His standard, therefore, increased the protein requirement above that of the Haecker standard by about 20 per cent. He also combined diges-

[1] Minn. Exp. Sta. Bul. 218.

[2] Cornell Exp. Sta. Bul. 323.

TABLE XIII

REQUIREMENTS FOR MILK PRODUCTION BY HAECKER STANDARD

For Each Pound of Milk Testing, per cent	Digestible Crude Protein, lb.	Carbohydrates, lb.	Fat, lb.	Total Digestible Nutrients, lb.
3.0	0.047	0.20	0.017	0.285
3.5	0.049	0.22	0.019	0.312
4.0	0.054	0.24	0.021	0.341
4.5	0.057	0.26	0.023	0.369
5.0	0.060	0.28	0.024	0.394
5.5	0.064	0.30	0.026	0.422
6.0	0.067	0.32	0.028	0.450
6.5	0.072	0.34	0.029	0.477

tible protein, digestible crude fiber, digestible nitrogen-free extract, and digestible fat multiplied by $2\frac{1}{4}$ into what is called total digestible nutrients. This was done to simplify the computation of a ration. Other standards, including the Haecker standard, have later been expressed in this manner. Table XIV is the standard as suggested by Savage.

TABLE XIV

SAVAGE'S FEEDING STANDARD FOR DAIRY COWS

	Digestible Crude Protein, lb.	Total Digestible Nutrients, lb.
Milking cows *		
For maintenance of 1000-lb. cow........	0.700	7.925
For product in addition to maintenance:		
For 1 lb. of milk testing 3.0 per cent.....	0.0567	0.2870
For 1 lb. of milk testing 3.5 per cent.....	0.0608	0.3185
For 1 lb. of milk testing 4.0 per cent.....	0.0648	0.3497
For 1 lb. of milk testing 4.5 per cent.....	0.0689	0.3787
For 1 lb. of milk testing 5.0 per cent.....	0.0729	0.4048
For 1 lb. of milk testing 5.5 per cent.....	0.0770	0.4311
For 1 lb. of milk testing 6.0 per cent.....	0.0810	0.4572
For 1 lb. of milk testing 6.5 per cent.....	0.0851	0.4835

* In rations for milking cows there should be not less than 24 pounds of dry matter. The nutritive ratio should not be wider than 1 to 6 or narrower than 1 to $4\frac{1}{2}$. About two-thirds of the dry matter in the ration should come from the roughage and one-third from the grain, except that for the heaviest producers relatively more may come from the grain.

TABLE XV

MORRISON FEEDING STANDARDS *

	Digestible Protein		Total Digestible Nutrients		Net Energy	
	Minimum Allowance Advised, lb.	Recommended for Good Cows under Usual Conditions, lb.	Minimum Allowance Advised, lb.	Recommended for Good Cows under Usual Conditions, lb.	Minimum Allowance Advised, therms	Recommended fo Good Cows under Usual Conditions, therms
Dairy Cows						
A. For maintenance (per head daily)						
700-lb. cow	0.440	0.476	5.13	5.81	4.10	4.65
750-lb. cow	0.467	0.506	5.45	6.18	4.36	4.94
800-lb. cow	0.494	0.536	5.77	6.53	4.62	5.22
850-lb. cow	0.521	0.564	6.08	6.88	4.86	5.50
900-lb. cow	0.547	0.593	6.38	7.23	5.10	5.78
950-lb. cow	0.574	0.621	6.69	7.58	5.35	6.06
1000-lb. cow	0.600	0.650	7.00	7.93	5.60	6.34
1050-lb. cow	0.626	0.678	7.30	8.27	5.84	6.62
1100-lb. cow	0.652	0.706	7.60	8.61	6.08	6.89
1150-lb. cow	0.677	0.734	7.90	8.95	6.32	7.16
1200-lb. cow	0.703	0.762	8.20	9.29	6.56	7.43
1250-lb. cow	0.730	0.790	8.51	9.64	6.81	7.71
1300-lb. cow	0.754	0.817	8.80	9.97	7.04	7.98
1350-lb. cow	0.779	0.844	9.09	10.29	7.27	8.23
1400-lb. cow	0.805	0.872	9.39	10.63	7.51	8.50
1450-lb. cow	0.829	0.898	9.67	10.96	7.74	8.77
1500-lb. cow	0.854	0.925	9.96	11.28	7.97	9.02
1550-lb. cow	0.878	0.952	10.25	11.61	8.20	9.29
1600-lb. cow	0.904	0.979	10.54	11.94	8.43	9.55
1650-lb. cow	0.928	1.005	10.82	12.26	8.66	9.81
1700-lb. cow	0.952	1.032	11.11	12.58	8.89	10.06
1750-lb. cow	0.976	1.058	11.39	12.90	9.11	10.32
1800-lb. cow	1.001	1.084	11.68	13.23	9.34	10.58
B. For milk production per pound of milk (To be added to allowance for maintenance)						
For 2.5 per cent milk	0.034	0.040	0.238	0.251	0.221	0.233
For 3.0 per cent milk	0.036	0.043	0.261	0.276	0.243	0.257
For 3.5 per cent milk	0.038	0.046	0.284	0.300	0.264	0.279
For 4.0 per cent milk	0.041	0.049	0.307	0.324	0.286	0.301
For 4.5 per cent milk	0.044	0.052	0.330	0.349	0.307	0.325
For 5.0 per cent milk	0.046	0.056	0.353	0.373	0.328	0.347
For 5.5 per cent milk	0.049	0.059	0.376	0.397	0.350	0.369
For 6.0 per cent milk	0.052	0.062	0.399	0.422	0.371	0.392
For 6.5 per cent milk	0.054	0.065	0.422	0.446	0.392	0.415
For 7.0 per cent milk	0.057	0.068	0.445	0.470	0.414	0.437

* These data are taken by the special permission of the Morrison Publishing Company from Feeds and Feeding, 20th Ed., by F. B. Morrison.

Morrison's Feeding Standard.—Morrison,[1] of the Cornell Experiment Station, has formulated a standard for dairy cattle based on experiments conducted at various experiment stations, and has given it in two forms, namely, for the minimum allowance advised, and for the recommended amount for good cows under usual conditions. The requirements are stated both in pounds of total digestible nutrients and in terms of net energy, so that one may use either system in calculating rations. This standard is largely used in the United States. Table XV gives the requirement for maintenance and for the production of milk as recommended by this standard.

Production-value Type

Kellner Feeding Standard.—Kellner, a German investigator, published in 1907 a feeding standard[2] based upon starch as the unit of measure. He also took into account not only the digestibility of the feeds, as calculated from the amount lost in the feces, but also the entire loss from the body and the energy expended in digesting and passing the food through the body. The amount remaining is what the animal has left to use in a productive way. Kellner's standard is thus more complete than the previous ones. The standard for maintenance of a 1000-pound animal is 0.6 pound of digestible protein and 6.35 pounds of starch equivalent. Table XVI gives the standard as formulated by Kellner.

TABLE XVI

Kellner's Feeding Standard for Dairy Cows

Daily Yield of Milk, lb.	Dry Matter in Total Ration, lb.	Digestible Substances				
		Protein, lb.	Starch Equivalent, lb.	Crude Protein, lb.	Fat, lb.	Nitrogen-free Extract and Crude Fiber, lb.
10	22–27	1.0–1.3	7.8– 8.3	1.2–1.6	0.3	9.8–10.2
20	25–29	1.6–1.9	9.8–11.2	1.9–2.3	0.5	11.5–12.8
30	27–33	2.2–2.5	11.8–13.9	2.6–3.0	0.6	12.9–14.7
40	27–34	2.8–3.2	13.9–16.6	3.3–3.8	0.8	13.9–15.3

[1] Feeds and Feeding, 20th Ed., Morrison.

[2] The Scientific Feeding of Farm Animals, Kellner.

Any of the feeds the composition of which is known may be converted readily into the starch equivalent by using the following factors: Digestible protein × 0.94, + digestible fat × 2.41, + nitrogen-free extract, + crude fiber = total starch equivalent. The starch equivalent in turn can be converted into net energy by a method worked out by Armsby and Kellner.[1]

Armsby Feeding Standard.—By the use of the respiration apparatus, Kellner and Zuntz were able to determine how much of the energy of the feed was required for mastication, digestion, and assimilation; Armsby went a step further by using the respiration calorimeter. He determined not only the energy required for mastication, digestion, and assimilation of the food, but also the amounts of heat and gases given off by the body. By means of his apparatus he was able to calculate the true net energy available in the various feeding stuffs. Table XVII shows what becomes of the digestible nutrients of corn meal, timothy hay, and wheat straw where fed to dairy cattle.

TABLE XVII

NET ENERGY FROM 100 POUNDS OF CORN MEAL, TIMOTHY HAY, AND WHEAT STRAW

	Gross Energy, therms	Energy Lost in			Available Energy Remaining, therms	Energy Lost in Work of Digestion, therms	Net Energy Remaining, therms
		Feces, therms	Methane, therms	Urine, therms			
100 lb. corn meal....	180.3	21.2	15.9	8.1	135.1	52.2	82.9
100 lb. timothy hay..	181.2	86.2	13.6	7.1	74.3	31.3	43.0
100 lb. wheat straw..	184.6	107.5	15.3	4.4	57.4	47.3	10.1
Expressed in Percentage							
Corn meal..........	100	12	9	4	75	29	46
Timothy hay.......	100	48	7	4	41	17	24
Wheat straw........	100	59	8	2	31	26	5

[1] U.S.D.A. Farmers' Bul. 346.

As seen from this table, the amount of energy lost in the gases and in the labor of mastication, digestion, and assimilation in some cases exceeds the amount lost in the feces and urine, the two latter being the only losses considered in the other standards. It is not the amount of digestible parts alone, but the net value for use in maintenance and production, that is essential. The Armsby standard is based, then, upon the actual work that the feed will perform.

Armsby based his ration on the digestible true protein and therms of net energy. The digestible true protein differs from the digestible crude protein in that true protein does not include free amino acids and amides, but since it is now generally agreed that the digestible crude protein is a better measure of the protein value of a feed than the true protein, the amount of true protein has been converted to digestible crude protein and is so given in this book. The net energy is based upon the calory as the unit, but in order to simplify the method Armsby suggested the name "therm," to apply to 1000 large calories.

A definite amount of digestible crude protein and net energy is required for the maintenance of animals of different sizes, and an additional definite amount is required for milk of different quantities and qualities. The amount of these substances required for maintenance is not based upon the weight of the animal, as in the other standards, but upon its body surface.

The immense amount of work necessary to determine the net energy value of any one feed made it impossible to secure data on a great many feeds. For this reason the actual net energy values of but very few have as yet been determined. Most of them have been computed from Kellner's data on the starch values. It has also been found that even those that have actually been run should be considered merely as averages. This is true because different samples of feeds will vary considerably. Their results, also, were secured with steers only; other classes of livestock may vary from this average. It has been shown by Eckles[1] that Armsby's figures are a little low for the best results with dairy cattle.

Table XVIII gives the maintenance requirements for animals of different sizes according to the Armsby standard, and Table XIX

[1] Mo. Exp. Sta. Res. Bul. 7.

shows the amount of digestible crude protein and net energy which should be added to the maintenance requirements in order to produce 1 pound of milk of different qualities.

TABLE XVIII

MAINTENANCE REQUIREMENTS FOR COWS BY ARMSBY STANDARD

Weight, lb.	Digestible Crude Protein, lb.	Net Energy, therms	Weight, lb.	Digestible Crude Protein, lb.	Net Energy, therms
750	0.456	4.95	1200	0.622	6.78
800	0.474	5.17	1250	0.638	6.96
850	0.494	5.38	1300	0.656	7.15
900	0.513	5.59	1350	0.672	7.33
950	0.531	5.80	1400	0.689	7.51
1000	0.550	6.00	1450	0.705	7.69
1050	0.569	6.20	1500	0.721	7.86
1100	0.586	6.39	1550	0.737	8.03
1150	0.603	6.58	1600	0.752	8.21

TABLE XIX

REQUIREMENTS FOR MILK PRODUCTION IN ADDITION TO MAINTENANCE BY ARMSBY STANDARD

For 1 Pound of Milk Testing, per cent	Digestible Crude Protein, lb.	Net Energy, therms
2.5	0.045	0.19
3.0	0.047	0.21
3.5	0.049	0.24
4.0	0.054	0.27
4.5	0.057	0.29
5.0	0.061	0.32
5.5	0.064	0.34
6.0	0.067	0.36
6.5	0.070	0.39
7.0	0.075	0.41

Limitations of Feeding Standards

A standard should be looked upon as a guide and cannot be used at all times. It must be departed from sometimes to suit the individuality of different animals, and at other times to meet conditions when the prices of certain types of feeds are too high. The most economical results may not always be secured by feeding according to a standard.

There are also many other factors, as brought out in the previous lecture, which are not taken into account in balancing rations. These factors include the more recent knowledge concerning the complete and incomplete proteins, the mineral requirements, the palatability, the succulence, the vitamins, and other requirements which go to make up a good ration. In other words, a ration may meet the requirements of a standard as far as food nutrients are concerned, but may be very undesirable from a physiological or economical standpoint.

Another difficulty with feeding standards is that they are too difficult for general use. Farmers do not take the time necessary to study them out. However, herdsmen and others interested in dairying should become acquainted with their use.

Feeding standards, as a rule, are quite accurate, and can be used very advantageously in showing the deficiencies of a ration which is being fed. It should be understood, however, that feeding standards, as well as the tables of nutrients, are but averages and will not apply to all feeds or to all conditions.

REFERENCES FOR FURTHER STUDY

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LECTURE IX

BALANCING RATIONS FOR INDIVIDUAL COWS

Balanced Rations

A BALANCED ration is the feed or combination of feeds which will supply the daily food requirements of an animal. To tell what these daily requirements are, the various feeding standards have been formulated. The next problem, then, is to adjust the feeds in such a way that they will meet the requirements. This is called balancing rations. It is very necessary that the student in dairying and any others interested in the feeding of dairy animals understand how rations are balanced.

In this lecture we shall take up the methods of balancing a ration for an individual cow by the Scandinavian, the Haecker, the Morrison, and the Armsby standards. The Wolff-Lehmann standard is used very little in this country at present, and the method used in the Savage system is so similar to that of the Morrison system that it will not be taken up. For convenience and for comparison, the same conditions will be considered in every case. It will be necessary, in order to have a balanced ration by the use of each standard, to vary the amounts of the different feed stuffs. The amount of roughage, however, will be kept the same throughout this problem.

Problem

Calculate a balanced ration for a cow weighing 1000 pounds and giving 25 pounds of 4 per cent milk. The following feeds are available:

Roughages	*Concentrates*
Red-clover hay	Wheat bran
Corn stover	Gluten feed
Corn silage	Cottonseed meal
	Corn meal

Scandinavian System.—In Lecture VIII it was learned that for maintenance a cow requires 1 feed unit for every 150 pounds

of weight and that she requires 1 additional unit for each 3 pounds of milk produced. In addition, it is necessary that the ration contain, for maintenance, not less than 0.065 pound of digestible protein for each 100 pounds of live weight and 0.05 pound of digestible protein for each pound of milk produced.

The requirements, then, for the particular cow in the problem would be as follows:

	Digestible Crude Protein, lb.	Feed Units
Maintenance of 1000-lb. cow	0.65	6.66⅔
25 lb. of 4 per cent milk	1.25	8.33⅓
Total	1.90	15.00

The problem now is to apportion the feeds so that they will supply these requirements and, at the same time, to keep in mind the characteristics of the different feeds. The amount of digestible protein can be ascertained from Table A in the Appendix, and the feed units from Table X in Lecture VIII.

For a trial ration we shall use the feeds in the following proportions:

	Digestible Crude Protein, lb.	Feed Units
Roughages:		
30 lb. corn silage	0.390	4.53
5 lb. clover hay	0.350	2.15
4 lb. corn stover	0.088	1.46
Concentrates:		
4 lb. corn meal	0.284	4.12
1 lb. gluten feed	0.227	1.14
1½ lb. wheat bran	0.197	1.17
1½ lb. cottonseed meal	0.509	1.97
Total	2.045	16.54
Requirements	1.900	15.00
Difference	+0.145	+1.54

It will be noticed that the protein is but little in excess of the requirements but that there are 1.54 feed units in excess. It will be necessary, therefore, to take away a little of the low-protein feed, which in this ration is corn meal. For a new trial we shall take away 1½ pounds of corn meal.

	Digestible Crude Protein, lb.	Feed Units
First trial ration	2.045	16.54
Deduct 1½ lb. corn meal	0.107	1.54
Total	1.938	15.00
Requirements	1.900	15.00
Difference	+0.038	0.00

The ration would then be very close to the requirements.

The ration balanced by this system would be as follows:

Roughages	*Concentrates*
30 lb. corn silage	2½ lb. corn meal
5 lb. clover hay	1 lb. gluten feed
4 lb. corn stover	1½ lb. wheat bran
	1½ lb. cottonseed meal

It would require, then, 6½ pounds of concentrates to fulfill the needs of the standard. This is about 1 pound of concentrates to each 3.8 pounds of milk.

Haecker Standard.—The Haecker standard was originally expressed in three terms, digestible crude protein, digestible carbohydrates, and digestible fat, although it has since been changed over to the protein and total-nutrients basis. In calculating the ration by this standard we shall use the later method, since it is the one commonly used.

By referring to Tables XII and XIII in Lecture VIII, it is seen that the maintenance requirement for a cow weighing 1000 pounds is 0.7 pound of digestible protein and 7.925 pounds of total digestible nutrients, and that for each pound of 4 per cent milk which the cow is giving she requires in addition 0.054 pound of digestible

protein and 0.341 pound of total digestible nutrients. The requirements, then, for the cow in the problem would be as follows:

	Digestible Crude Protein, lb.	Total Digestible Nutrients, lb.
Maintenance of 1000-lb. cow	0.70	7.925
For production of 25 lb. of 4 per cent milk	1.35	8.525
Total requirements	2.05	16.450

Table A in the Appendix contains the analyses of different feeds. For a trial ration, the same ration as was used in the Scandinavian system will be used. It is as follows:

First Trial Ration

	Digestible Crude Protein, lb.	Total Digestible Nutrients, lb.
Roughages:		
30 lb. of corn silage	0.390	5.610
5 lb. of red-clover hay	0.350	2.595
4 lb. of corn stover	0.088	2.088
Concentrates:		
2½ lb. of corn meal	0.178	2.015
1 lb. of gluten feed	0.227	0.774
1½ lb. of wheat bran	0.197	1.053
1½ lb. of cottonseed meal	0.509	1.104
Total	1.939	15.239
Requirements	2.050	16.450
Differences	−0.111	−1.211

The trial ration is deficient in both protein and total digestible nutrients but is lower in total digestible nutrients than in digestible protein. By looking at the feeds we see that corn meal is high in total digestible nutrients and at the same time quite low in protein. For the second trial, therefore, we shall add 1½ pounds of corn meal.

SECOND TRIAL RATION

	Digestible Crude Protein, lb.	Total Digestible Nutrients, lb.
First trial ration	1.938	15.239
1½ lb. corn meal	0.107	1.209
Total	2.045	16.448
Requirements	2.050	16.450
Difference	−0.005	−0.002

The ration is now not far from the requirements of the Haecker standard. It is as follows:

30 lb. corn silage	4 lb. corn meal
5 lb. clover hay	1 lb. gluten feed
4 lb. corn stover	1½ lb. wheat bran
	1½ lb. cottonseed meal

It would require, then, 8 pounds of concentrates to supply the requirements of this standard under the given conditions. This is about 1 pound of concentrates to each 3.1 pounds of milk.

Morrison Standard.—Morrison uses only two terms, digestible crude protein and total digestible nutrients. The total digestible nutrients are the sum of the digestible crude protein, the digestible carbohydrates, and the digestible fat multiplied by 2.25. The 2.25 is the factor used to convert the fat into its equivalent carbohydrate value. For milk production, as well as for maintenance, Morrison gives a minimum allowance and also the allowance recommended for good cows under usual conditions. The second figure is generally used.

By referring to Table XV in Lecture VIII, it may be seen that the maintenance requirement for a cow weighing 1000 pounds is 0.65 pound of digestible protein and 7.930 pounds of total digestible nutrients. It will be seen also that for each pound of 4 per cent milk the cow requires 0.049 pounds of digestible protein and 0.324 pound of total digestible nutrients in addition. The total require-

ments, then, for the particular cow in the problem would be as follows:

	Digestible Protein, lb.	Total Digestible Nutrients, lb.
Maintenance of a 1000-lb. cow	0.650	7.930
For production of 25 lb. of 4 per cent milk	1.225	8.100
Total requirements	1.875	16.030

In Table A in the Appendix the analyses of the different feeds can be ascertained. For a trial, the same ration as in the Scandinavian system may be used. It is as follows:

FIRST TRIAL RATION

	Digestible Protein, lb.	Total Digestible Nutrients, lb.
Roughage:		
30 lb. of corn silage	0.390	5.610
5 lb. of red-clover hay	0.350	2.595
4 lb. of corn stover	0.088	2.088
Concentrates:		
2½ lb. of corn meal	0.178	2.015
1 lb. of gluten feed	0.227	0.774
1½ lb. of wheat bran	0.197	1.053
1½ lb. of cottonseed meal	0.509	1.104
Total	1.939	15.239
Requirements	1.875	16.030
Difference	+0.064	−0.791

The first trial ration contains a slight excess of digestible protein but is deficient in total digestible nutrients. In the second trial, therefore, we shall add 1 pound of corn meal and subtract ½ pound of cottonseed meal:

SECOND TRIAL RATION

	Digestible Protein, lb.	Total Digestible Nutrients, lb.
First trial ration	1.939	15.239
1½ lb. corn meal	0.107	1.209
Deduct ½ lb. cottonseed meal	−0.170	−0.368
Total	1.876	16.080
Requirement	1.875	16.030
Difference	+0.001	+0.050

This ration is now not very far from the requirements of this standard, and is as follows:

Roughage	*Concentrates*
30 lb. of corn silage	4 lb. corn meal
5 lb. of clover hay	1 lb. of gluten feed
4 lb. of corn stover	1½ lb. of wheat bran
	1 lb. of cottonseed meal

It would require 7½ pounds of this mixture to supply the requirements of this standard. This would be about 1 pound of concentrate to each 3.33 pounds of milk produced.

Armsby Standard.—The Armsby standard is expressed in pounds of digestible crude protein and therms of net energy. By referring to Tables XVIII and XIX in Lecture VIII it can be seen that the maintenance requirement for a cow weighing 1000 pounds is 0.55 pound of digestible crude protein and 6 therms of net energy, and that for each pound of 4 per cent milk she requires 0.054 pound of digestible crude protein and 0.27 therm of net energy. From this it can be seen that the requirements are as follows:

	Digestible Crude Protein, lb.	Net Energy, therms
Maintenance of 1000-lb. cow	0.550	6.00
For production of 25 lb. of 4 per cent milk	1.350	6.75
Total requirements	1.900	12.75

In Table A in the Appendix the digestible crude protein and net energy of the various feeding stuffs can be found. The same ration which was found to meet the requirements of the Scandinavian standard will be used in the first trial:

FIRST TRIAL RATION

	Digestible Crude Protein, lb.	Net Energy, therms
Roughages:		
30 lb. of corn silage	0.390	5.610
5 lb. of red-clover hay	0.350	2.140
4 lb. of corn stover	0.088	1.080
Concentrates:		
2½ lb. of corn meal	0.178	1.980
1 lb. of gluten feed	0.227	0.761
1½ lb. of wheat bran	0.197	0.896
1½ lb. of cottonseed meal	0.509	1.085
Total	1.939	13.552
Requirements	1.900	12.750
Difference	+0.039	+0.802

The first trial ration supplies 0.039 pound of digestible crude protein and 0.802 therm of net energy more than is required. It will be necessary, then, to take away some of the low-protein feed. Accordingly, we shall remove 1½ pounds of corn stover for the second trial ration. This ration will be as follows:

SECOND TRIAL RATION

	Digestible Crude Protein, lb.	Net Energy, therms
First trial ration	1.939	13.552
Deduct 1½ lb. of corn stover	0.033	.783
Total	1.906	12.769
Requirements	1.900	12.750
Difference	+0.006	+0.019

This ration now just about meets the requirements of the Armsby standard. It is as follows:

Roughages	*Concentrates*
30 lb. of corn silage	2½ lb. of corn meal
5 lb. of red-clover hay	1 lb. of gluten feed
2½ lb. of corn stover	1½ lb. of wheat bran
	1½ lb. of cottonseed meal

This standard would require 6½ pounds of concentrates to fill its needs. This is about 1 pound of grain to each 3.7 pounds of milk given by the cow.

The foregoing problems show how rations can be balanced. With a little practice one becomes able to adjust a ration by adding, for example, a little of one feed and taking away a little of another, thus obtaining the right proportion to meet the requirements. A method has been suggested for the exact calculation of balanced rations, but this is usually unnecessary as one can come near enough by the above methods for all practical purposes.

Comparison of Feeding Standards

It is not possible to make a direct comparison of all the feeding standards as they are not all expressed in the same terms. In Table XX, however, the requirements for maintenance and for the production of 1 pound of 4 per cent milk are brought together so that a comparison can be made. The Wolff-Lehmann and the Haecker systems have been converted to the total-digestible-nutrient basis, although the production of 1 pound of milk with the Wolff-Lehmann system has been omitted since this system includes the maintenance requirement wit hthe production requirement.

Table XX shows that there is very little difference in the maintenance requirements as far as comparisons can be made. The requirements of the Savage standard for milk production, however, are slightly higher than the others. A direct comparison cannot be made between the Armsby or the Scandinavian standards and the other standards. With the rations balanced in the problem of the first part of this lecture, the amount of concentrates required by these standards was considerably less than was required with the Haecker or Morrison standards. It has been found that for maximum pro-

TABLE XX

Comparison of Feeding Standards

Name of Standard	Maintenance of 1000-lb. Cow				Production of 1 Lb. of 4% Milk			
	Digestible				Digestible			
	Crude Protein, lb.	Total Nutrients, lb.	Feed Units	Net Energy, therms	Crude Protein, lb.	Total Nutrients, lb.	Feed Units	Net Energy, therms
Wolff–Lehmann	0.70	8.925						
Haecker.......	0.70	7.925	......	....	0.0540	0.3410		
Savage........	0.70	7.925	......	....	0.0648	0.3497		
Morrison*......	0.65	7.93	......	6.34	0.049	0.324		0.301
Scandinavian..	0.65	....	$6\frac{2}{3}$	....	0.0500	....	$\frac{1}{3}$	
Armsby.......	0.55	....	......	6	0.054	....	......	0.270

* Recommended for good cows under usual conditions.

duction more feed is required than is provided for by the Armsby standard. At times, however, it may be economical to feed less than would be fed for maximum flow. The requirements of the Scandinavian standard do not seem to be far from those of the Armsby system.

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LECTURE X

BALANCING RATIONS FOR THE HERD

The method of balancing rations as given in the last lecture is adapted to individual cows. When it comes to feeding a herd, it is not practical to figure a ration for each individual animal as this would require too much time and effort. The method described can be used, however, if the average cow in the herd is taken as the basis of the calculation. By this method the average weight of the cows and their average production and butterfat test serve as the basis of calculating a ration as outlined in the foregoing lecture. Such a ration, when fed according to specific rules, based upon the production of the animals, should give good results. Another method of calculating a ration for a herd is to balance the protein of the grain mixture to go with the kind of roughage that is to be fed and to disregard the carbohydrates and fat. This method, though not accurate, does have the advantage that it is easy to figure and should give very satisfactory results.

Balancing Rations According to Average Cow in the Herd

When balancing rations according to the average cow in the herd it is necessary to know somewhere near the average weight of the cows in the herd and their average production and butterfat test.

All dairymen should make a practice of weighing their milk, and from this they can figure their average production.

When the test of butterfat is not known the following table will be of help in making an estimate:

	Per Cent
Herd of all pure-bred or high-grade Jerseys or Guernseys	5.0
Mixed herd with some Guernseys and Jerseys	4.5
Herd of Ayrshires, Brown Swiss, or mixed breeds	4.0
Herd of all Holsteins	3.5

If the weights of the cows are not known the following table will help to make an estimate:

	Pounds
Herd of Jerseys	800– 900
Herd of Guernseys, Ayrshires, or mixed breed	1000–1200
Herd of Brown Swiss	1100–1300
Herd of Holsteins	1200–1400

As an example of this method put into practice, assume a herd of mixed breeds giving on the average 24 pounds of milk, which is to be fed corn silage and mixed clover and timothy hay for roughage, and a mixture of corn meal, oats, wheat bran, and cottonseed meal for concentrates. The problem is to calculate how much of each should be fed. It is first necessary to figure the requirements of the average animal in the herd. In figuring the requirements, let us use the Morrison Standard given in Table XV for good cows under usual conditions, although any of the standards could be used in the same way.

	Digestible Protein, lb.	*Total Digestible Nutrients, lb.*
Maintenance, 1100 lb.	0.706	8.610
Milk, 24 lb., 4 per cent fat	1.176	7.776
Total requirements	1.882	16.386

According to the standard, the average animal in this herd should be fed so that she will obtain 1.882 pounds of digestible protein and 16.386 pounds of total digestible nutrients per day.

The next problem is to find a ration that supplies the nutrients as needed according to the calculations made. As already has been noted, when hay and silage are fed together, a cow will consume approximately 3 pounds of silage and 1 pound of hay for each 100 pounds of live weight. The remainder of the nutrients must be made up from the concentrate mixture. This information together with the rule of feeding 1 pound of concentrate to each 3½ pounds of milk produced will be used in this trial:

	Digestible Protein, lb.	Total Digestible Nutrients, lb.
33 lb. corn silage	0.429	6.171
11 lb. mixed hay	0.484	5.280
2 lb. corn meal	0.142	1.612
2 lb. wheat bran	0.262	1.404
2 lb. ground oats	0.188	1.430
1 lb. cottonseed	0.339	0.736
Total in ration	1.844	16.633
Requirements	1.882	16.386

This ration is slightly low in digestible protein and slightly high in total digestible nutrients but is close enough for practical purposes.

The concentrate part of this ration should then be mixed in the proportion as given above, namely, 2 parts corn meal, 2 parts wheat bran, 2 parts ground oats, and 1 part of cottonseed meal, and fed to the different cows in the herd in proportion to the amount of milk that they are giving as shown in Table XXI. The cows should be fed all the roughage that they will clean up.

Balancing Rations by the Protein Method [1]

For general farm use, a simple method of balancing a ration for a herd is required, and even the one just described may sometimes prove too elaborate to be practical. Since there is seldom a deficiency in carbohydrates and fats when the animals have all the roughage that they can eat, a roughly balanced ration may be obtained by balancing the protein of the grain mixture to go with the kind of roughage used and disregarding the carbohydrates and fats.

The roughages can be divided into the three groups given above as follows:

I. Low-protein Group: Timothy hay, corn stover, straw, corn silage, or any other non-legume. Percentage of digestible protein required in grain ratio, 18 to 22.

[1] W. Va. Exp. Sta. Circ. 42.

II. Medium-protein Group: Mixed hay, clover and silage, or other roughage, with at least half of the roughage legume. Percentage of digestible protein required in grain mixture, 15 to 18.

III. High-protein Group: Clover hay, alfalfa hay, soy-bean hay, or any of the legume roughages. Percentage of digestible protein required in grain mixture, 12 to 15.

Making up a Grain Mixture for the Herd.—As an example of this method of making up a ration for a dairy herd, let us assume that we have on hand alfalfa hay and corn silage for roughage, which are in the medium-protein group, and that we have available corn meal, ground oats, wheat bran, and cottonseed meal. By referring to Table A in the Appendix we get the following figures for protein:

100 lb. of corn meal contains 7.1 lb. of digestible crude protein.
100 lb. of wheat bran contains 13.1 lb. of digestible crude protein.
100 lb. of ground oats contains 9.4 lb. of digestible crude protein.
100 lb. of cottonseed meal contains 33.9 lb. of digestible crude protein.
Then 400 lb. of the mixture contains 63.5 lb. of digestible crude protein.
$63.5 \div 400 = 0.159$, or 15.9 per cent of digestible crude protein.

By referring to the groups of roughages, it will be noted that, when the roughage is in the medium-protein group, the protein in the grain mixture should be from 15 to 18 per cent. This ration, then, should fulfill the requirements, provided, of course, it meets the needs of the animals as to bulk, variety, palatability, physiological effect, mineral content, and so forth.

Now let us assume that instead of alfalfa and silage for roughage we have only timothy hay and corn stover, which are in the low-protein group, and that we have the same concentrates as before. It would be necessary to add more of the high-protein feeds as follows:

400 lb. of the mixture contains 63.5 lb. of digestible crude protein.
100 lb. of cottonseed meal contains 33.9 lb. of digestible crude protein.
500 lb. of the new mixture contains 97.4 lb. of digestible crude protein.
$97.4 \div 500 = 0.195$, or 19.5 per cent of digestible crude protein.

By referring to the groups of roughages, it will be noted that when the roughage is in the low-protein group the digestible protein in the grain mixture should be from 18 to 22 per cent. This ration

fulfills these requirements and therefore should be a good one under the given conditions.

Now suppose that the roughages consist of alfalfa hay alone, which is in the high-protein roughage group, and that the same concentrates are available. It would be necessary to add a low-protein concentrate, such as corn meal, to the first ration, as follows:

400 lb. of the mixture contains 63.5 lb. of digestible crude protein.
100 lb. of corn meal contains 7.1 lb. of digestible crude protein.
500 lb. of the new mixture contains 70.6 lb. of digestible crude protein.
$70.6 \div 500 = 0.141$, or 14.1 per cent of digestible crude protein.

We note that the grain mixture in the high-protein group should be between 12 and 15 per cent, and hence the foregoing ration would fulfill the requirements; yet, if desirable for any reason, the protein content of the ration could be still lower.

It is comparatively easy to balance a grain mixture in this way for any kind of roughage. If the roughage is low-grade, use a higher protein percentage in the grain mixture, and vice versa. It is important, however, to keep in mind the characteristics of the feeds when making up the grain ration, and always to feed the ration according to the production of the individual cows in the herd as shown in Table XXI.

It is also well to consider the cost of the protein and total digestible nutrients in the feeds used to make up the ration, and always to take the cheapest, everything else being equal, as is illustrated later in this lecture.

Selecting Feeds for a Dairy Ration

In selecting a combination of feeds to make a balanced ration for a dairy herd, the requirements of a physically satisfactory ration must always be maintained. Prices of purchased feeds must also be considered and the selections made on the basis of relative cost and quality.

A ration must be planned with regard to the available roughage. It is desirable to make the best possible use of all home-grown feeds. Cows may be given all the roughage that they will readily clean up. The kinds of concentrates selected will depend on the quality of the roughage. Such concentrates must be chosen as will supplement the

roughage to give, in the whole ration, the needed amount of protein, total digestible nutrients, and other nutritive properties, as well as the desirable physical characteristics of bulk, palatability, and laxativeness. When silage is fed, the problem of getting a palatable and laxative ration is greatly simplified. With silage, it is possible, if prices make it desirable, to feed some unpalatable and constipating concentrates.

The principal characteristics of legume hays are palatability, laxativeness, and high protein and calcium content; it is possible, therefore, to supplement them with concentrates comparatively low in protein and calcium and constipating in effect. The concentrates and the roughages should dovetail each other, so that the whole ration fulfills all the requirements of a good ration.

When any requirement is fulfilled largely or entirely by the roughage, little or none of that requirement need be supplied by the concentrates. On the other hand, when little or none of the requirement is supplied by the roughage, most or all of that requirement must be furnished by the concentrates.

Adding Minerals to the Ration

Dairy cows must have salt regularly. It is usually advisable also to allow free access to it at all times. A popular practice, even although cows are given free access to it, is to add 1 pound of salt to each 100 pounds of concentrates, or 20 pounds to each ton.

Legume hay is a good source of calcium, and wheat bran, cottonseed meal, and linseed oilmeal are good sources of phosphorus. If legume hay and one of these concentrates are fed along with other feeds in a balanced ration the cow's requirements for these minerals are usually met.

If rations known to be low in these elements are fed, or if cows show abnormal appetites for bones, wood, or soil, the ration may be lacking in one or both of these elements. If calcium is deficient, 20 pounds of finely ground limestone may be added to each ton of grain, or the herd may be allowed access to a mixture of 2 parts of ground limestone to 1 part of salt. If both phosphorus and calcium are deficient, 20 to 30 pounds of steamed bone meal should be added to each ton of the grain mixture, or the herd may be given access to a mixture of 2 parts of bone meal and 1 part salt.

Mixing the Ration

When the concentrate ration for the herd has been calculated, the next step is to mix the ingredients together in a uniform manner. It is necessary that the mixing be done thoroughly; otherwise different parts of the ration will vary in composition.

In mixing, the different concentrates should be spread out in thin layers on a clean, smooth floor, one on top of another. The salt and mineral should also be added at this time. The whole mixture

FIG. 13.—Students mixing a grain ration.

should then be shoveled over at least three times, to insure complete mixing, before it is finally shoveled into the bin or sacks for storage. The amount that should be mixed at one time depends upon the size of the herd and upon the storage space. Often the mixed feed is stored in bins holding a definite amount. It is usually best to mix sufficient at each mixing to fill this bin. Whenever possible, it is well to have each ingredient in the ration in terms of 100 pounds, for in this way the use of a scale is not necessary if the feeds are in 100-pound sacks. Of course this is not possible for the minerals, and sometimes not for other ingredients.

Amount of Concentrates to Feed

The practice of feeding all cows in the milking herd the same amounts of grain is a costly one because it usually underfeeds the best producers and overfeeds the low producers in the herd. The amount of grain required by cows varies according to the quantity and richness of the milk and the quality of the roughage ration. Such practices as feeding 1 pound of grain to 3 or 4 pounds of milk, or 1 pound of grain per day per pound of fat produced per week, are better than feeding all cows alike, but they do not go far enough and they do not take into account the quality or quantity of roughage consumed.

TABLE XXI

Grain-feeding Guide for Stable-fed Cows

Pounds of Milk Produced Daily	Pounds of Grain Required Daily			
	By Cows Testing under 4% When Roughage is		By Cows Testing over 4% When Roughage is	
	Good	Fair	Good	Fair
15	1	4	3	6.5
20	3	6	5.5	9
25	5	8	8	11.5*
30	7	10	10.5*	13.5
35	9	12*	13	16
40	11*	14	15.5	18
45	13	16	18	20
50	15	18	20.5	22

* Never feed a cow more grain than she can handle with safety. Many cows in heavy production will not remain in good health when fed the amounts of grain required to continue heavy production without loss of live weight.

Table XXI may be useful as a guide in determining the amount of grain to feed cows. It gives consideration in a general way to variations in daily milk production, in butterfat test, and in the quality of the roughage fed. To use the table, first determine whether the roughage would be classed as good or fair. Good roughage includes well-cured, green, leafy hay fed with or without corn

silage of good quality. Fair roughage includes hay of poorer quality than that referred to above, fed with or without silage or limited amounts of stover or straw. The next step is to consider the daily milk production and its test. To illustrate, a cow giving 25 pounds of milk testing 5 per cent and receiving good roughage would require 8 pounds of grain daily, or, if the roughage was fair, the grain requirement would be 11.5 pounds. A cow giving 35 pounds of 3.5 per cent milk on good roughage would require 9 pounds of grain, or on fair roughage, 12 pounds of grain daily.

Determining the Cost of the Ration

The cost of the ration should be figured on every farm. This is especially true of the grain ration, a large proportion of which is often purchased. The following table will show the cost, at given prices, of 100 pounds of digestible crude protein and 100 pounds of total digestible nutrients of certain feeds:

	Digestible Crude Protein, lb.	Total Digestible Nutrients, lb.	Price per Ton	Price per 100 Lb.	Cost of 100 Lb. of Digestible Crude Protein	Cost of 100 Lb. of Total Digestible Nutrients
Wheat bran	13.1	70.2	$28.00	$1.40	$10.68	$1.99
Ground oats	9.4	71.5	30.00	1.50	15.95	2.09
Corn meal (No. 2)	7.1	80.6	28.00	1.40	19.72	1.73
Cottonseed meal (41%)	33.9	73.6	35.00	1.75	5.16	2.38

The following explanation illustrates how the cost of digestible crude protein and total digestible nutrients is determined: Dividing the cost of 100 pounds of wheat bran ($1.40) by the number of pounds of digestible crude protein in 100 pounds of wheat bran (13.1), one gets 10.68 cents, the cost of 1 pound of digestible crude protein; and multiplying this result by 100 gives $10.68, the cost of 100 pounds of digestible crude protein. In like manner, dividing the cost of 100 pounds of wheat bran ($1.40) by the pounds of total digestible nutrients in 100 pounds of wheat bran (70.2) gives 1.99 cents, the cost of 1 pound of total digestible nutrients; multiplying this result by 100 gives $1.99, the cost of 100 pounds of total

digestible nutrients. By this method the cost of the digestible crude protein and the total digestible nutrients in each feed can be determined.

It can be seen by this illustration that, at the prices assumed, the relative cost of total digestible nutrients does not vary as much as that of the digestible crude protein. In the purchase of feeds the cost of these items should be considered rather than the cost of 100 pounds of feed. The cheapest ration will usually contain the concentrates that furnish the digestible crude protein at the cheapest rate as well as that which furnishes the total digestible nutrients relatively cheaply.

If a ration is to be mixed containing 100 pounds of each of the feeds in the above illustration, the cost of the ration would be as follows:

ACTUAL COST OF GRAIN RATION

100 lb. of wheat bran costs	$1.40
100 lb. of ground oats costs	1.50
100 lb. of corn meal (No. 2) costs	1.40
100 lb. of cottonseed meal (41%) costs	1.75
400 lb. of mixture costs	6.05
100 lb. of mixture costs	1.51
100 lb. of digestible crude protein costs	12.79
100 lb. of total digestible nutrients costs	2.05

In a similar manner the cost of any ration can be figured, as well as the cost of 100 pounds of total digestible nutrients. The same method can also be followed in figuring the cost of 100 therms of net energy.

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LECTURE XI

FEEDING FOR MILK PRODUCTION

Causes of Milk Secretion

Milk secretion is stimulated by two factors: the first is the action of hormones, or stimulating substances, secreted by a ductless gland; the second is a nervous reaction brought about by the treatment which the animal receives.[1] The hormone stimulus seems to be the predominating one for a period of time after parturition and is more or less independent of the feed supply. As lactation advances, however, the nervous stimulus gradually replaces the hormone stimulus, which gradually dies out. The nervous stimulus is entirely dependent upon the food supply and the treatment received by the cow. The hormone stimulation, however, is due to the heredity of the cow and will continue for some time even after all food has been removed. It is nature's provision to feed the young even though the mother herself may suffer.

Eckles and Palmer [2] fed several cows which had just freshened on rations sufficient only for maintenance, and in certain cows the milk flow continued the same for twenty-two to thirty days. The animals were able to maintain this flow by drawing upon their surplus fat and flesh. One cow which was thin at the start was so weak at the end of thirty days on this ration that she had difficulty in getting up, and staggered considerably in her walk, but her milk production actually increased. This is a striking example of the strength of the hormone stimulus which the cow receives at parturition.

Resting the Cow

Heavy milk production is a severe drain upon a dairy cow, and for this reason it is very important that the cow be given a rest of six to eight weeks between each lactation period. The length of

[1] Mo. Exp. Sta. Res. Bul. 24.
[2] Mo. Exp. Sta. Res. Bul. 25.

time necessary will depend upon the condition of the cow and the amount of milk which she is producing. For a heavy producer, or for a cow in poor flesh, two months should be allowed, so that she will have ample time to rest and store up any materials such as calcium and phosphorus which she may need in greater quantities than she can consume during the stress of heavy production. Very few cows need less than six weeks' dry period.

The importance of getting a cow in proper condition when she is dry cannot be overemphasized. The condition that she is in at the time of freshening will determine in a large measure the extent of her production. She should be in an excellent state of health and carry a surplus of fat when she freshens. This fat is available for immediate use to the cow after she freshens and makes possible a normal increase in production before it is advisable to feed her heavily on a grain ration. It has been found that a cow that has been given a good rest and is in good condition at time of freshening will usually produce more heavily than one that has been given little or no rest. She will reach a higher daily production early in her lactation period and will continue high milk production throughout the entire period. One of the reasons why cows seem to have alternate "off years" is that the feeder fails to give them ample time and opportunity to freshen in good condition.

Cows that are due to freshen should be turned out daily in fine weather and should be provided with a clean, well-bedded box stall.

Drying the Cow

Frequently it is easy to dry the cow, as too many of them go dry by themselves after milking for a short time. Sometimes, however, the hormone stimulation remains quite strong and the cow will continue to give a good flow of milk up to the time of freshening. This is often advanced as a reason for not drying a cow off. A cow should always be given a rest, however. If she is producing as little as 8 or 10 pounds a day she can easily be dried off by increasing the time between milkings for a few days and then ceasing altogether to milk her. At this period the stimulus is practically all of the nervous type and the cow can be dried off very easily.

There are three common ways of drying off the cow, namely, incomplete milking, intermittent milking, and complete cessation. A study at the Minnesota Experiment Station [1] showed that complete cessation of milking can safely be recommended with cows producing as much as 20 pounds of milk daily. Cows could be dried off in less time with this method than with the other two methods, and no significant difference could be noted in the quantity and quality of the milk in the following lactation. In drying a cow by this method the udder fills up until pressure great enough to stop secretion is established in the udder. After secretion stops, the milk is gradually resorbed from the gland until it becomes dry. The cow should not be milked during the resorption period as this releases the pressure within the gland and secretion is again initiated, resulting in a prolonged period of drying off.

Feeding the Dry Cow before Parturition

If the cow is dry during the summer or early fall and is on good pasture she will need very little extra feed or care before parturition. A pasture separate from the general herd is desirable as there is then less danger of injury. Under these conditions the cow will usually need very little grain. If she is in poor condition, however, she should be fed a light ration containing such feeds as ground oats, wheat bran, and corn meal, or ground barley. Corn should not be fed in large quantities at this period as it is a heating feed. The cow should be in good condition at the time of freshening as her production depends upon her getting a good start.

If the dry period occurs in the winter the ration should consist of 20 to 30 pounds of corn silage with a liberal amount of legume hay and a grain mixture containing such feeds as linseed meal, wheat bran, ground oats, and, if the cow is in poor condition, corn meal. The regular herd ration is often fed with good results, but a ration a little lower in protein is more desirable.

About two weeks before the cow is due to freshen, the grain ration should be considerably reduced and at that time the cow should be fed a ration which will keep the bowels in a laxative condition. Corn should be removed frcm the ration, and a mixture of

[1] Jour. Dairy Sci. 16:69.

equal parts of wheat bran and ground oats is often fed at this time with good results. It is sometimes necessary to give the cow a dose of Epsom salts or a quart of raw linseed oil a few days before parturition. Freedom from post-parturient troubles are in a large measure due to the care with which a cow is handled during the few weeks previous to parturition.

Feeding a Cow just after Parturition

The grain ration for the first few days after parturition should be light in character and should be fed in small amounts. A bran mash made by moistening the bran with warm water is the only grain which should be fed at first. It has a cooling effect on the cow and is slightly laxative. She can also be given some legume hay and a limited amount of corn silage. If the weather is cold her water should be warmed slightly. A mixture of oats, bran, and linseed meal can be used to replace the bran mash after the first day or two.

Getting the Cow on Full Feed

After the first three or four days, if the cow is in good condition, she can gradually be given the regular herd ration just as fast as her physical condition will permit. If the udder is swollen the amount of grain must be kept down until the congestion disappears. Great care should always be exercised in increasing the cow's ration to full feed. Oftentimes, with heavy producing cows, full feed will not be reached for an entire month after parturition. The heavy-milking cows usually lose weight during the first month as they are drawing on their reserve for milk production.

Under ordinary conditions, one can begin on the fourth or fifth day after freshening to feed 4 or 5 pounds of the regular grain ration, and this can be increased at the rate of 1 pound every two or three days until the cow reaches her maximum production. It is often hard to judge when the maximum has been reached. The cow should be given enough feed to supply the amount needed in the milk and to keep her from dropping off in her weight. If she is giving 30 pounds of milk per day and is receiving 9 pounds of grain, and if it is not sure that she has reached her maximum production,

the feed should be increased slowly to possibly 12 pounds and the effect upon the cow watched carefully. If she responds with more milk, then a further increase should be attempted. If, however, she does not give any increase in milk production within two or three days, the amount of grain should be gradually diminished until she is receiving just the amount to which she will respond.

Feeding the Milking Herd

In feeding the milking herd for production, it is well to keep in mind the requirements for a good dairy ration which have been brought out in a previous lecture. A cow should receive an abundance of feed, containing plenty of nutrients in the correct proportions and made up of feeding stuffs that are palatable and low in price. The other requirements of a good ration should also be given consideration.

Weight a Good Index.—The condition of the cow is a good index as to whether she is being properly fed. A cow usually loses weight during the first four to six weeks of her lactation, the amount lost depending upon her condition at the time of freshening and her ability as a producer. For the next five to six months the weight of the cow should remain fairly constant, the exact length of time depending upon the time of her next calving.

From two to four months before parturition the cow usually increases in weight, partly on account of the growth of the fetus, but more largely on account of the storage of body fat which may later be used for milk production. The cow should be so fed that she will not lose weight during the greater part of her lactation period.

Feeding Cows as Individuals.—The dairy cow should be fed as an individual. Each cow has her peculiar likes and dislikes, and these must be catered to if the best results are to be obtained. It is never advisable to feed all cows in the herd the same amount, as each has different requirements. Some are larger than others, some give more milk than others, and some give milk of higher quality than others. All these factors should be taken into consideration. Heifers during their first and second lactation periods should be fed a little more liberally than mature cows, because they are still growing. Cows that possess a highly nervous temperament are often fed

a ration with a wider nutritive ratio than those that tend to take on fat.

Avoid Overfeeding.—Although liberal feeding is advisable, overfeeding must be guarded against. If a cow is being fed more than she requires for milk which she is producing, she is probably storing up fat which, although not entirely wasted, is not giving any immediate return. It would be much better if the cow were fed just as much as she requires for the milk she is producing. Any-

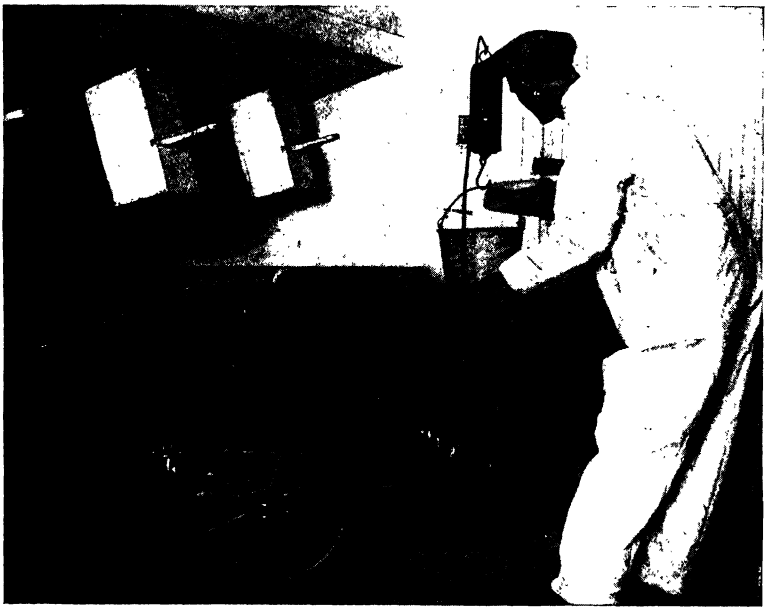

FIG. 14.—Weighing feed is an important step in successful feeding.

thing over that amount is largely wasted. Sometimes overfeeding results in the cow's going off feed. If this happens, the grain ration should be immediately cut down, and the cow should be fed only light, laxative feeds for a few days. After this she may be slowly put back on her full ration.

The Amount of Nutrients Required for the Growth of the Fetus.—It has always been known that, with the onset of pregnancy, the dairy cow must provide the nutrients not only for the production of milk but also for the building up and the maintaining

of the developing fetus. Eckles[1] found from experimental results that the amount of nutrients necessary to develop the bovine fetus is so small that it cannot be measured by ordinary means of experimentation. He analyzed four Jersey calves at birth and found that they contained an average of 73.09 per cent of water. The amniotic fluid weighed about 30 pounds, 95 per cent of which was water. The placenta weighed 18 pounds, approximately 85 per cent of which was water. A Jersey cow, on this basis, produces a total of only 15 to 20 pounds, and the Holstein 20 to 25 pounds of dry matter in the fetus and accompanying fluid and membrane. Eckles found that, on a dry-matter basis, a Jersey calf at birth is equivalent to 110 to 170 pounds of Jersey milk, and that the Holstein calf is equivalent to 200 to 275 pounds of Holstein milk. Other investigators have found that the carrying of the calf was a slight but significant drain upon the mother's milk production. All experimental work points to the fact that the amount of feed required to grow the fetus is not such that it must be seriously considered during the feeding period.

Order of Feeding.—The cow is a creature of habit and expects her feed at regular intervals. Regularity is much more important than any order of feeding, although to give the feed regularly some system of feeding must be followed. There is, perhaps, no best order of feeding, but certain factors should be considered. Hay, which is likely to cause dust in the barn, and feeds such as silage and roots which tend to impart taints to the milk, should be fed after the milking rather than before. The grain is often fed before milking or at the time of milking. Frequently it is desirable to feed the grain on the silage. If this is done it does not seem necessary to have so much bulk in the grain mixture.

A good system would be to feed the grain before milking and the silage just as soon as the milking was done. The hay could then be fed just as soon as the cows had finished their silage. This would give time to turn the cows out, in fine weather. If corn stover were to be fed it could be fed out in the lot at this time. The same order could be followed in the evening. This would leave the mangers filled with hay the last thing at night so that the cows would have as much time as necessary to clean it up. When cows are milked

[1] Mo. Agr. Exp. Sta. Res. Bul. 26.

oftener than twice a day, the number of feedings is usually increased.

Feeding Equipment.—The farm should be so arranged and the equipment should be such that the feeding can be done with a minimum amount of labor. The grain should be kept, if possible, in bins on the second floor, from which it can be run directly into a feeding truck. If this is not possible it can be kept in sacks or in bins in a room on the first floor, where it can be poured or shoveled into the feeding truck. The truck may be run on a track in front of the cows, or it may be on wheels and be pushed in front of them. Often, in the smaller dairies, the grain is kept in a large feed box in the barn and the feeder simply feeds out of this box. Whatever the system, it is very necessary that the feed be kept well covered or out of reach of the cows, as they are very likely to be foundered if they do get to it. The choice of a system should depend upon the size of the herd. It is usually advisable to weigh the feed to each cow. Some dairymen, however, prefer to measure it. This can be done if the feeder is careful to weigh a measure or two and so become accustomed to the amount which the measure will hold. It should always be borne in mind, when feeding by measure, that feeds vary considerably in weight. In any method there should be a simple feed sheet to show the amount that each cow is to be fed.

For convenience in the feeding of silage, the silo should be reasonably near the cow barn. The silage in the smaller dairies is often pitched out of the silo upon the barn floor, whence it is carried in baskets to the cows. In larger dairies it is usually thrown into a silage truck which runs either on wheels or on a track and which may be pushed around in front of the cows as in feeding the grain. Beets can be fed in the same way. They are usually stored in a root cellar, which should be easily accessible.

The hay chute from the mow should be located in a convenient place where the hay can be thrown down into the barn and from there fed to the cows in the quantities desired. The hay may be loaded into a small hayrack, the weight of which is known, and pulled on to scales. In this way the actual weight of the hay for the entire herd may be determined. It can then be distributed according to the feeder's judgment. When baled hay is fed it is much

easier to handle, but unless care is taken there is a tendency to feed more than when the hay is fed loose.

WATERING

Milk contains approximately 87 per cent of water, and so it is very necessary that the cows be allowed an abundant supply at all times.

The amount of water required by dairy cows depends upon the amount of milk they are producing, the kind of feed they are being fed, and the temperature of the atmosphere. The Idaho Experiment Station [1] found that, under ordinary conditions, dry cows consumed 73.5 pounds of water per day, medium producing cows (30.2 pounds of milk) consumed 109.7 pounds per day, and heavy producing cows (82.4 pounds of milk) consumed 191.4 pounds per day. It is apparent that a large amount of water is necessary even for dry cows. The importance of having water before the cows at all times can easily be seen.

A cow will not drink all the water she needs for the most profitable production of milk unless she can get it frequently, without discomfort, and at a temperature not below that of well or spring water. Many dairymen are successfully using automatic drinking cups in their barns in order to supply these conditions.

PREPARATION OF FEEDS

Grinding.—The grinding of grains increases their digestibility only if they are hard seeds which otherwise might pass through the digestive tract unbroken. The amount thus lost might be fairly large, perhaps as much as 10 to 20 per cent, in the feed of dairy cows, although in the feed of heifers and calves it is much less because young animals seem to masticate their food better than older ones. This seems to indicate, except where hogs run after cattle, that there would be considerable loss if the grain were not ground. Sometimes when mature corn is put in the silo the grains pass through the animal undigested. It is always advisable to grind the grain for the dairy herd.

[1] Jour. Dairy Sci. 17: 265.

As a rule it is not profitable, nor does it increase digestibility, to cut up the roughages. When cut, however, they are easier to feed and the cows will usually eat more of the coarser parts. This is especially true of corn stover which, when cut into small pieces, is much easier to handle in the barn, as the cows will consume a large proportion and the refuse can be conveniently utilized for bedding. Alfalfa is sometimes ground and sold as alfalfa meal, but this does not increase its feeding value.

Soaking.—As a general rule, the soaking of grain is not necessary as it does not add anything to its digestibility or palatability. However, wheat bran is often mixed with warm water, in which condition it is known as bran mash. It is a good conditioner for cows just before and after freshening or at other times when they are out of condition. It has been shown [1] that when cows are given free access to water there is no advantage in soaking beet pulp or other feeds.

Predigesting.—Predigesting roughages by means of converters, in which the roughage is cut, mixed with a starter or converted, packed into drums or wooden tanks, then steamed or soaked with warm water, and allowed to stand for a sufficient length of time for fermentation to take place, have not proved economical.[2] The dairy cow seems to be able to convert her own roughages more economically than it can be done by the feeder.

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LECTURE XII

FEED AND MANAGEMENT OF COWS ON TEST

THE improvement of the dairy breeds which has been brought about by the systems of testing of the various breed associations has been of great importance to the dairy industry. Changes in testing methods have of course been necessary. For example, the short-time tests—7-day and 30-day—have been discarded and superseded by the 305- or 365-day tests. More recently the herd test, in which the entire herd is tested for the year, has been gaining in popularity. This gives a system of studying the blood lines of dairy herds which was not possible when only the best cows were under test. It is important in this system to keep the entire herd at the maximum production year after year, and this is not so easy as to make high records from a few of the best cows, or to make one good herd test record.

The first essential for large records is good cows. Unless the cows are capable of large production, no amount of good feeding and handling will make it possible for them to produce a large amount of milk or butterfat. If the cows are capable of making a large record, then it is up to the feeder and caretaker to get the production out of them. No two men will use exactly the same methods in doing this; each will work out a system which is best suited to his individual conditions. It has been said that "the secret of large records is so simple that many men do not successfully follow it. The mysterious method is but a liberal application of good common sense with untiring faithfulness to the cow." [1] The directions given in the following paragraphs are merely guides and are not given as set rules from which one cannot vary.

Feeding Cows Previous to the Testing Period.—One of the most important considerations in the feeding of a cow for a high record is to have her in good healthy condition at the beginning of

[1] N. J. Exp. Sta. Circ. 127.

the testing period. To do this it is necessary to give the animal that is to be put on test the best of care from birth, and by liberal and judicious feeding have the heifer large, vigorous, and in good flesh at the time of freshening. If a mature animal is to be put on test, she should be dry for six to ten weeks so that she will have ample time to rest and to build up her reserve for the time of heavy milk production. In feeding for high records it is very important that the cow be put in a good thrifty condition and in fairly good flesh while dry. This is known as "fitting." It requires a liberal

FIG. 15.—A well arranged test-cow stable.

feeding of grain, the amount depending upon the condition of the cow and upon her ability to handle feed. The grain ration should be light, palatable, and not too high in protein. The following rations have been fed successfully during the fitting periods:

Ration 1	*Ration* 2
250 lb. ground oats	100 lb. corn meal or barley
200 lb. wheat bran	200 lb. wheat bran
150 lb. corn meal or hominy	200 lb. ground oats
9 lb. salt	100 lb. linseed meal
6 lb. steamed bone meal	6 lb. salt

The amount of grain that should be fed at this time depends largely upon the condition and the size of the cow. It is very seldom wise to feed more than 10 or 12 pounds for the larger breeds or 6 to 8 pounds for the smaller ones. Some feeders feed as much as 20 pounds per day, but when this is done great care should be taken that the cows are not thrown off feed.

If good pasture is available the cow may be allowed to secure her roughage from it; if it is not available, corn silage and alfalfa hay usually form the foundation of the ration. Other legume hay may be substituted for the alfalfa, and beets are equally as good as silage. Beet pulp moistened with water is satisfactory as a succulent, either by itself or in conjunction with corn silage.

Care of Cow at Freshening Time.—A few days before freshening, the cow should be changed to a cooling ration. The following has been recommended for this period:

Ration 3

100 lb. wheat bran
100 lb. ground oats

This ration should be fed at the rate of 4 to 8 pounds a day along with some beets or beet pulp. The cow should then be put in a well-bedded stall and watched carefully. It is particularly necessary to see that she has plenty of water and that her bowels are kept loose.

After the first signs of calving, if no abnormal conditions develop, it is best to leave the cow entirely alone until immediately after calving, when the fetal membrane that covers the calf's nose should be removed so that the calf will not suffocate. The cow should then be given some warm water and a bran mash. It is sometimes recommended that a little Epsom salts be added with the bran mash. About 3 to 4 pounds of bran and enough warm water to make a soft mash may be given. The cow should not be fed again for about twelve hours, when she may be given some good, clean legume hay and a little grain ration of a laxative nature.

Getting the Cow on Feed.—For the first three or four days after freshening a cow should get a very small amount of the same ration which she received before freshening, which should consist mostly of bran, ground oats, and linseed meal. In fact, she should

not be fed much until she has gained strength and her udders and digestive organs are in normal condition. Usually on the fourth or fifth day she can be put on the regular test mixture, but it should be some time before she is given very much. The grain ration can be gradually raised until the cow is getting as much as she can handle.

Feeding for High Records.—In feeding for high records it should be remembered that there is a long time to make the record and the cow that milks heavily during the entire lactation is the one that is going to make the highest one. Such cows should be fed so that they do not reach full ration until about a month after freshening. The aim should be to get them on their maximum production after about a month and to hold them there throughout the year. The grain ration should be increased gradually as long as the cow maintains a good appetite and responds with an increase in milk flow. When the cow ceases to increase in milk production, which usually occurs about four to six weeks after calving, her grain ration should be cut down a couple of pounds a day and she should be fed at this rate for some time. The percentage of protein in the grain ration depends upon the roughage which is being fed. If good legume is being fed, 16 to 18 per cent protein is considered sufficient. If, however, the hay is not all leguminous, it may be necessary to increase it to 20 per cent protein. Some feeders lower the protein in the ration, during the last six months of the test period, to 12 or 15 per cent or less. The amount of grain fed to cows on long-time tests seldom should be more than 10 to 15 pounds. Usually not more than 20 pounds of grain per day are fed at any time, even for the very heavy producers. The world's champion dairy cow, *Carnation Ormsby Butter King,* although a very large cow, was not fed extremely heavily on grain. She averaged about 20 pounds of a commercial grain mixture daily. She was also fed 12 pounds of beet pulp soaked in water containing 2 pounds of molasses. She was fed light in silage averaging only about 15 pounds, but was fed all the alfalfa hay that she would clean up readily, which ranged from 20 pounds in the summer to 40 pounds in the winter. She was given 60 pounds of green feed daily during the summer months and an average of about 25 pounds of sliced beets daily during the test period.

The following grain rations have been used successfully:

Ration 4	*Ration* 5
200 lb. corn meal or hominy	100 lb. dried distillers' grains
200 lb. ground barley	100 lb. wheat bran
200 lb. ground oats	100 lb. hominy
200 lb. linseed meal	50 lb. gluten feed
200 lb. wheat bran	50 lb. ground oats
150 lb. cottonseed meal	100 lb. cottonseed meal
100 lb. gluten feed	10 lb. charcoal
100 lb. dried beet pulp	6 lb. salt

The roughage of a cow on yearly test is important. She should have all the good clean legume hay that she will eat. Silage is used successfully but not in large amounts. Usually about 15 to 30 pounds of silage is fed, depending upon the size of the animal. Beets are used extensively, but often they are not available. Very often beet pulp is fed. It should be fed at the rate of 6 to 10 pounds of dry pulp per day. This is usually soaked with water and fed wet. Molasses is often fed on the beet pulp. Green crops may be fed in the summer in place of silage. Pasture can be used if it is handy to the barn and abundant. Care should also be taken that the cows are given plenty of minerals throughout the year.

Feeding Cows on Herd Test.—Usually cows are not fed so heavily when they are on herd test as when they are on official test, for the feeder is thinking of continued records rather than one high record. A cow that is going to continue through several lactations must be given every advantage and not be pushed too heavily at any time. Usually a limited amount of grain is fed—very often not as much as her production would call for if she were being fed according to the ordinary recommendation. A very successful Ayrshire feeder states that he very seldom feeds heifers producing as much as 40 pounds of milk per day more than 9 pounds of a grain ration containing 15 per cent protein. He attempts to feed his mature cows in accordance with their requirements. A successful Holstein feeder feeds a grain ration containing from 16 to 17 per cent crude protein at the rate of 1 pound of grain to each 4.5 pounds of milk with a maximum limit of 18 pounds per day for mature cows and 13 pounds per day for two-year-old heifers, no matter how high they go in production. These feeders of course feed excellent roughage,

consisting of alfalfa hay, corn silage, and some beet pulp. The general recommendations given in the previous lecture on feeding the dairy herd apply to cows on herd test.

The following grain rations have been used successfully:

Ration 6

300 lb. wheat bran
400 lb. crushed oats
200 lb. corn meal
300 lb. linseed oil meal
12 lb. salt

Ration 7

500 lb. ground oats
500 lb. wheat bran
400 lb. yellow hominy
300 lb. linseed meal
250 lb. dried brewers' grains
30 lb. bone meal
20 lb. salt

Management of Cow on Test.—Cows on test do better when they are treated regularly. It is well for one man to handle the cows throughout the test as most cows respond much better to a feeder to whom they are accustomed. The feeder should study his cows. Some have unusual appetites and will respond to certain feeds which others do not relish. It is necessary for the feeder to watch for these individual peculiarities and to handle and feed the cows accordingly. When a ration is found to appeal to an individual cow it should be fed to her even though the other cows do not care for it.

At the first sign of a disposition on the part of any cow to refuse her feed, the ration should be cut down for a couple of feeds and then gradually brought back to the normal amount.

Effect of Feeding on the Fat Percentage.—It is a general belief among feeders that the ration greatly influences the fat percentage. Experimental data have not shown this to be so, although some feeds may have a stimulating effect for a short time. The effect of feeds very high in fat is only temporary. Ground flax seed and soy beans perhaps have as great an influence as any of the feeds, and even their effect is not pronounced and some cows may not respond to them.[1]

Influence of Galactogogues on the Fat Percentage.—Many people believe that it is possible to increase the percentage of fat in the milk of a cow by feeding certain galactogogues. There is undoubtedly a somewhat general belief that some successful feeders have

[1] Jour. Dairy Sci. 10: 70.

gained a part of their success by means of methods not generally known to the public. As a matter of fact, the different breed associations have made certain qualifications and sometimes have even required the feeder to take an oath and to sign an affidavit that he has not practiced unusual methods in feeding.

Several experiments have been conducted to determine the effect of certain galactogogues upon the yield of milk and the percentage of fat. Table XXII has been taken from the results of some work done at the Pennsylvania State College.[1]

TABLE XXII

EFFECT OF VARIOUS GALACTOGOGUES ON MILK YIELD AND PERCENTAGE OF FAT

The Kind of Galactogogue	Number of Trials	Number Increased in Milk Yield	Number Decreased in Milk Yield	Number Increased in Fat Percentage	Number Decreased in Fat Percentage
Sodium bicarbonate	10	10	0	5	5
Gentian	10	5	5	5	5
Ginger	10	3	7	10	0
Nux vomica	9	4	5	3	6
Pilocarpine hydrochlor. (injected)	6	2	4	3	3
Malt extract	10	7	3	5	5
Alcohol (external to udder)	6	2	4	3	3

All ten cows to which sodium bicarbonate was fed showed a slight increase in milk production, but the tests were not repeated a sufficient number of times to determine that these slight increases were not due to natural causes. In all the cows which were fed ginger, in ounce doses twice a day, there was a slight increase in the percentage of fat in the milk, but in most of them also a slight decrease in the milk yield, so that the total fat was not increased. The other drugs did not seem to have very much effect on either the milk yield or the percentage of fat in the milk.

[1] Pa. Exp. Sta. Rept. 1915–1916.

At the Iowa Experiment Station [1] it was found that alcohol, castor oil, Epsom salts, pituitrin, pilocarpine, and aloes had no effect upon the milk yield. Hayes and Thomas [2] found that air-slaked lime had a beneficial effect upon the milk flow. None of the drugs which they used seemed to have any effect in increasing the percentage of butterfat.

Influence of Stage of Lactation on Milk Yield.—The effect of stage of lactation upon milk production is quite well known. Data taken from 428 lactation periods at the Iowa Experiment Station [3] show that, in Jerseys and Guernseys, the highest milk yield is obtained during the first month of lactation and from that time on there is a very gradual decline until the eighth or ninth month, after which there is a very rapid decline until the end. In Holsteins and Ayrshires the second month is the highest in milk production, and from then on the decline is very similar to that of other breeds.

Influence of Stage of Lactation on the Percentage of Butterfat.—The most extensive study that has been reported concerning the effect of stage of lactation upon the percentage of fat is that of Ragsdale and Turner.[4] They used a total of 4045 cows, consisting of 3763 advanced-registry cows of the Guernsey breed, 299 register-of-merit cows of the Jersey breed, and 95 Holsteins from the University of Missouri herd. Their results show that with the Jersey and Guernsey breeds the percentage of fat dropped off from the first month to the second and there was then a very gradual increase from month to month until about the ninth or tenth month, after which there was a somewhat greater increase. The Holstein breed followed the same general curve, with the exception that they did not reach the low point until the third month. Table XXIII gives the results.

Protein and Energy in a Ration.— It is the general practice of feeders of cows on advanced-registry tests to supply an excess of protein and energy above that required by feeding standards. In fact, they usually feed the cows all that they will consume. No amount of forced feeding will produce high records unless the cow

[1] Jour. Dairy Sci. 4: 74.
[2] Jour. Agr. Res. 19: 123.
[3] Jour. Dairy Sci. 7: 255.
[4] Jour. Dairy Sci. 5: 22.

TABLE XXIII

INFLUENCE OF STAGE OF LACTATION UPON THE PERCENTAGE OF BUTTERFAT

Month of Lactation	Guernseys (3863), per cent	Jerseys (299), per cent	Holsteins (95), per cent
1	4.63	4.89	3.24
2	4.59	4.82	3.01
3	4.71	4.88	2.99
4	4.85	5.10	3.02
5	4.97	5.13	3.01
6	5.08	5.26	3.08
7	5.16	5.40	3.11
8	5.22	5.43	3.16
9	5.29	5.50	3.19
10	5.39	5.58	3.27
11	5.49	5.60	3.32
12	5.60	5.73	3.49

has inherited high milk-producing qualities. On the other hand, it is only by heavy feeding that high records have been produced.

A study of twenty tests was made at the Pennsylvania State College,[1] in which the exact amount of feeds given to the animals was known. The four main breeds of cattle were included in the test: there were ten Guernseys, six Ayrshires, three Jerseys, and one Holstein.

The amount of true protein and net energy of the ration fed was calculated. This was compared with the requirements of the different cows for net energy and true protein, as denoted by the Armsby feeding standard, the average weight of the cows, their production, and the percentage of butterfat in their milk being taken into consideration. It was found that with few exceptions the cows were extravagantly fed if the feeding standard could be considered a true measure. The twenty cows were fed 27.23 per cent more true protein and 16.94 per cent more energy for the production of 1 pound of milk under forced feeding than was required by the Armsby feeding standard. They were fed 25.88 per cent more true protein and 16.46 per cent more energy, to produce a pound of butterfat, than would have been required if they had been fed exactly

[1] Pa. Exp. Sta. Rept. 1915–1916.

according to the Armsby feeding standard. It should be realized, however, that these figures represent what the cows were fed; there are no data to show that they might not have done practically as well if they had been fed according to the standard. Nevertheless, since most feeders practice this method there is apparently good foundation for believing that this high nutritive plane is desirable for sustained production. Of late years there seems to be a tendency to feed cows on test on a lower plane, especially in regard to the protein. There seems to be some reason to believe that if the cows are fed too high a protein ration there will be more breeding troubles; and since the most desirable type of record is one that includes the production of a calf, this should be encouraged.

Advanced-registry Conditions Compared with Ordinary Ones.—The question is often asked: How much more do cows kept under test conditions produce than cows kept under average herd conditions? An investigation at the Beltsville Station [1] showed that cows kept under test conditions produced approximately 50 per cent more milk and butterfat than those kept under average herd conditions. This is a very important point to remember in buying cows on the basis of records. A record of 600 pounds of butterfat under test conditions would be equivalent to approximately 400 pounds under average herd conditions.

Feed Consumed by Large Producers.—The following data are presented to show just what some of the large-producing cows have been fed while on test:

The Jersey cow, *Lad's Iota,*[2] produced 18,632 pounds of milk and 1048.07 pounds of butterfat in a year. She started her record in April, 1921. This cow is described as a great feeder. She was fed as much as 27 pounds of grain, consisting of 9 pounds of rolled oats, 8 pounds of corn, 6 pounds of bran, and 3 to 4 pounds of oil meal. She was on clover pasture from the first of May to the first of October, but she was also fed clover hay and 4 pounds of beet pulp in addition. When she was taken off pasture she was fed silage and kale and was soon eating about 35 pounds daily of each. In November her grain ration was changed to 4 pounds of each of the following feeds: oats, bran, mill-run, corn, and oil meal, a total of

[1] Jour. Dairy Sci. 10: 283.
[2] Jersey Bul. 41: 843.

20 pounds of grain per day. This was later changed to the proportion of 2 pounds of oats and 2 pounds of bran to 1 of oil meal, but the total amount remained the same until the end.

The Holstein cow, *Belle Pontiac* 46321 *C. H. B.*,[1] produced 27,017 pounds of milk and 1573 pounds of butter in a year. She freshened June 19, 1920, after having been dry about six weeks. She started out very easily on a light feed of wheat bran and oil meal with green alfalfa for roughage. About the first of July, green mangels, fresh from the field, with the tops on, were given her to the extent of about a bushel and a half a day. As soon as she settled down to work she was put on a ration consisting of 2 pounds of bran, 6 pounds of oil cake, 1 pound of gluten, and 2 pounds of crushed oats, with a maximum of 12 pounds of cottonseed meal. She ate 30 and 33 pounds of this ration per day. She was also fed from 60 to 70 pounds of roots, 25 pounds of corn silage, and all the alfalfa hay that she wanted. About April 5 the ration was changed radically because the supply of silage was exhausted. The roots were increased to 150 pounds per day, the silage and cottonseed were cut out entirely, and the oil cake reduced to half, so that the ration stood for the rest of the year as follows: 2 pounds of bran, 2 pounds of crushed oats, 1 pound of oil cake, I pound of cream of wheat. To each feed was added ¼ pound of salt and a handful of charcoal. Eight pounds of this grain ration was fed at a time, making a total of 32 pounds a day.

Another famous Holstein cow, *Segis Pietertje Prospect* 221856,[2] produced 37,384.1 pounds of milk and 1445.9 pounds of butter in one year. She started on official test, December 1, 1919. This cow was dry for a little over two months preparatory to her test. During this time she was fitted on a ration consisting of equal parts of ground oats, bran, hominy, and oil meal, with some salt and charcoal. She received a small amount of beet pulp and a few beets.

After freshening she was at first fed very conservatively, receiving 17 pounds of grain daily. Her feed was gradually increased until March. It was then noticed that this pace was a little too heavy; accordingly, her feed was reduced. Table XXIV shows very clearly her feeding schedule.

[1] Holstein-Friesian World 18: 2744.

[2] Holstein-Friesian World 17: 6242.

TABLE XXIV

DAILY RATION OF *Segis Pietertje Prospect*

Month	Grain, lb.	Beet Pulp, lb.	Hay, lb.	Beets, lb.	Italian Rye Grass, lb.	Molasses, lb.	Oats, lb.	Sweet Corn, lb.
December	16	3	20	36	......	2		
January	22	5	25	56	......	2		
February	23	6	25	56	......	2		
March	25	6	30	36	10	3		
April	23	6	25	60	15	3		
May	23	6	20	60	25	3		
June	23	6	20	50	30	3		
July	21	5	20	40	......	3	40	
August	22	5	22	35	......	3	35	
September	22	6	23	48	......	3	10	20
October	22	6	25	56	......	3	......	25
November	21	6	28	60	......	3		
December	21	6	30	60	......	3		

The grain mixture was as follows:

6 parts ground oats	4 parts bran	3 parts corn meal
3 parts hominy	1 part cottonseed meal	2 parts soy beans
3 parts oil meal	1 part ground flax seed	1 part gluten

1 lb. of charcoal to 100 lb. of grain—salt at all times

Molasses was fed with the beet pulp. She received approximately 1 pound of grain to 4.6 pounds of milk produced.

Countess Prue, a seven-year-old Guernsey cow,[1] produced 18,629.9 pounds of milk and 1103.28 pounds of butterfat in one year ending November 29, 1920. During the year she was fed 19 to 22 pounds of a grain mixture made up of a large variety of concentrates which were modified considerably at different periods. In winter she received, in addition, 15 to 20 pounds of soaked beet pulp, 21 to 31 pounds of silage, and 15 to 21 pounds of mixed hay. In summer, soiling crops were fed instead of silage, and in autumn roots were added to the ration.

[1] Guernsey Breeders' Jour. 18: 704.

Of the Ayrshire breed, *Garclaugh May Mischief*[1] has produced 25,329.0 pounds of milk and 894.91 pounds of fat. During her record she consumed 4946 pounds of concentrates, 668 pounds of dried beet pulp, 11,200 pounds of corn silage, 22,300 pounds of beets, 2780 pounds of hay, and a small amount of soiling crops.

It can easily be seen by these records that large-producing cows consume large quantities of feed and are able to take care of it efficiently. Variety and palatability play very important parts in the feeding of these cows. The management of the test cow is very important, and the records made depend almost entirely upon proper management. It requires the utmost skill on the feeder's part to be able to tell when the cow is eating all she can, taking care not to give her too much feed, thereby causing her to lose her appetite and consequently fall down in her production. In three of the accounts given above there were certain days when the cows were reported slightly off feed, but by the utmost skill on the part of the feeders they were brought back without serious results. Special emphasis is laid on the way the cows were handled and fed. Much of the honor of high records should go to the feeder and caretaker, but no amount of care or feed will cause a cow to produce more than her inheritance permits.

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[1] Ayshire Quarterly, July, 1916.

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LECTURE XIII

EFFECT OF ABNORMAL AND UNUSUAL RATIONS

THE efficient production of milk usually calls for feeding a well-balanced ration, fortified in all the essentials of a good ration and divided between roughages and concentrates. Many times, however, such rations are not fed, either because of ignorance on the part of the feeder, or because of abnormal conditions which justify a departure from ordinary methods. A feeder, however, should understand what should be expected under such conditions. The following discussion will give some experimental evidence on the results obtained by different methods of feeding.

FEEDING UNBALANCED RATIONS

A ration is said to be balanced when it contains the different nutrients in the proper proportion to meet all the requirements for maintenance and production. When any of the necessary constituents are not given in sufficient quantities the animal cannot produce milk up to the limit of her ability. A cow cannot change materially and permanently the composition of her milk, and its production is controlled by the constituents of her feed. An excess of protein, for instance, may be used to some extent for the production of energy, although it is not usually economical to produce energy in this way. An excess of energy-producing material, however, cannot take the place of protein.

Insufficient Feed.—One of the common mistakes that many feeders make is to use insufficient feed—rations low in both protein and energy. The rational feeding of dairy cows is of greater importance than is often realized. Many cows that are now causing a loss to their owners, if fed properly, would yield a good return. The tests below show that the milch cows of the United States are probably much better than their records indicate. The feeding of suffi-

cient feed would no doubt greatly increase the average production of the cows in this country.

An experiment conducted at the Maryland Experiment Station [1] shows the effect of good feeding. A herd of eight cows was kept under observation by the Station on a farm for one year. The following year the same animals were kept at the Station, where a good feeding system was followed. Table XXV shows the effect of proper feeding on ordinary cows:

TABLE XXV

COMPARISON OF FEEDING METHODS

(Maryland Experiment Station)

Number of Cows	First Year, on Farm, Lb. of Milk	Second Year, at Station, Lb. of Milk	Average lb. Milk per Day, Best Week, First Year	Average lb. Milk per Day, Best Week, Second Year
1	4.004	6.092	27	40
2	4.122	5.051	21	33
3	5.192	6.163	27	40
4	4.537	6.134	27	48
5	6.097	6.995	31	35
6	4.035	7.995	27	57
7	6.357	6.828	38	33
8	4.653	5.465	24	37

A similar experiment, though somewhat more extensive, was undertaken by the New York Experiment Station.[2] A herd representative of the cows in the farming community near Cornell University was selected. During one year, these cows were fed and handled by their owner, but records of the feed used and the milk produced were kept by the Experiment Station. The following two years the animals were kept in the college barns and fed balanced rations. They were then returned to the farms, where records were kept for the fourth year. Table XXVI shows the average yearly production during the four years and the length of the lactation period. This table shows that the cows, during the two years at

[1] Data furnished to one of the authors by Doane.

[2] N. Y., Cornell Exp. Sta. Bul. 222.

TABLE XXVI

INFLUENCE OF LIBERAL FEEDING ON PRODUCTION

Year	How Fed	Average Yearly Production			Lactation Period, Weeks
		Milk, lb.	Fat, per cent	Fat, lb.	
1900	Poorly	3360	4.4	148	34
1901–1902	Liberally	6621	4.6	301	43
1903	Poorly	4492	4.3	190	39

the college, produced a yearly average of 2695 pounds more milk and 132 pounds more fat than they averaged during the two years at the farm. The increased production in 1903 over 1900 was probably due to their improved physical condition after two years of proper feeding. Proper feeding increased the length of the lactation period from 34 to 43 weeks. Needless to say, not only was there an increase in production but also the enterprise was much more profitable when they were fed liberally.

Heavy Feeding.—It is usually profitable to give to cows that have the ability to produce large amounts of milk all that is necessary in order to reach their normal limit of production. The amount of feed required for maintenance by cows of the same weight is practically the same, and the differences in production are due to the amount of feed consumed over that required for maintenance. This being so, it is more profitable to produce milk from a cow that will produce 20 pounds than from one that will produce only 10 pounds. The higher producer is more economical because she produces more milk with the same amount of food for maintenance as the low producer. Two of the low-producing cows must be maintained to produce the amount of milk that is obtained from one of the higher producers. Although it is true that high production is the most economical, it does not follow that cows should be forced to the limit of their production. The last few pounds may cost more than they are worth. There is a point in the feeding of dairy cows where it is not profitable to use more feed in order to get a higher production. The law of diminishing returns is brought into operation because the proportion of concentrates required is

greatly increased, with the result that a very high percentage of the feed comes from the high-priced concentrates. In advanced-registry feeding it may pay to get the last few pounds of milk from the cow because of the value of the record. The extra milk, however, may be produced at an actual loss.

Research has been carried on at a number of the experiment stations to determine the economy of heavy and normal feeding for dairy cattle. In an experiment at the Wisconsin Experiment Station [1] sixteen cows were fed what are called, respectively, heavy and normal rations. The heavy rations consisted of an average of 110 pounds of dry matter for each 100 pounds of milk and an average of 23.8 pounds of dry matter for each pound of fat. The normal rations averaged 81.8 pounds of dry matter for each 100 pounds of milk and an average of 21.7 pounds of dry matter for each pound of fat.

All the cows in the lot fed the heavy grain rations consumed more dry matter to a pound of milk and butterfat than those fed the normal ration. The cows fed the heavy ration did not maintain the full flow of milk during the following two months of the experiment any better than the normally fed cows. There was actually a small difference in favor of the normally fed animals, perhaps owing to digestive disorders or to overfeeding. The conclusion drawn from the experiment was that it was unprofitable to feed the cows more than a medium amount of grain unless they were animals with marked dairy tendencies. It has been found that dairy cows will digest a medium to low ration better than a heavy one.

Rations Low in Protein.—In an experiment at the Illinois Experiment Station, [2] two groups of ten cows each were fed rations equal except in amount of protein, as follows:

Lot 1	Pounds	Lot 2	Pounds
Corn silage	30	Corn silage	30
Clover hay	8	Timothy hay	5
Gluten feed	$4\frac{2}{3}$	Clover hay	3
Ground corn	$3\frac{1}{3}$	Ground corn	8

[1] Wisc. Exp. Sta. Bul. 116.
[2] Ill. Exp. Sta. Bul. 159.

The ration of the first lot contained 1 pound of digestible protein to 6 pounds of digestible carbohydrates and fats, which is a balanced ration for cows giving 40 pounds of milk daily. The ration of the second lot contained 1 pound of digestible protein to 11 pounds of digestible carbohydrates and fats, which is a ration too low in protein for cows giving 40 pounds of milk.

Lot 1, which received the balanced ration, produced 1.7 pounds more milk during the preliminary week of the trial; during the second week, or the first week of the trial, the increase was 5.8 pounds for each cow daily; and in the seventh week the gain was 13.2 pounds. The average for the nineteen weeks of the test was 10.65 pounds of milk for each cow daily, in favor of the cows fed the balanced ration.

The cows receiving the balanced ration produced approximately one-third more than those receiving the low-protein ration. Six and one-half cows on the balanced ration produced as much as nine cows on the ration low in protein.

The cows that received the balanced ration were in better physical condition and had good flesh at the end of the trial, whereas those receiving the unbalanced ration lost greatly in flesh and their subsequent production was also reduced. The carbohydrates and fats could not take the place of the protein.

Rations High in Protein.—In a research project at the Virginia Experiment Station [1] a group of cows was fed a ration high in protein. The ration consisted of 2 pounds of cottonseed meal, 2 pounds of bran, 7 pounds of corn gluten meal, and 40 pounds of silage. This had a nutritive ratio of 1 : 2.4, and the grain ration contained 28.2 per cent of digestible protein. The cows refused 25 per cent of their ration, but the amount they consumed supplied them with sufficient energy and two and one-half times as much protein as was necessary. The excess amount of protein was digested, and the coefficient of digestibility of it and the other nutrients agreed very closely with the average coefficients. The cows were able to use this excess protein by voiding the excess of nitrogen in urine and using the remainder to furnish energy or to supply fat. The animals on this ration were in excellent condition throughout the experiment.

[1] Va. Exp. Sta. Tech. Bul. 12.

Amount of Protein to Feed.—Although an excess of protein does not seem to be detrimental to the cow, yet for economical milk production it is usually best to feed somewhat near the minimum requirements. A study was made at the Cornell Experiment Station [1] in which the production of cows fed a 24 per cent protein grain mixture, a 20 per cent protein grain mixture, and a 16 per cent protein grain mixture was compared. All cows were fed mixed hay and corn silage. The experiment extended over a period of three years, and the results are given in Table XXVII. The conclusion of this study was that a 16 per cent total protein concentrate mixture, fed with No. 2 timothy-clover mixed hay, and corn silage as roughage, gave as high production when fed at the rate of 1 pound of concentrates to each 3½ pounds of milk produced as either a 20 per cent or a 24 per cent total protein concentrated mixture. There was no evidence of a stimulating effect of protein on milk secretion. The 16 per cent ration furnished sufficient protein for maintenance and 127.8 per cent of the protein required for the production of the milk and seemed to be adequate for efficient and economical milk production.

TABLE XXVII

PRODUCTION OF COWS ON VARYING LEVELS OF PROTEIN FEEDING, CORNELL EXPERIMENT STATION

Protein, per cent	Production of Milk in Pounds		
	1928–1929	1929–1930	1930–1931
16	9,262	9577	9565
20	10,066	9689	9673
24	9,410	9804	9542

Rations High in Energy.—The workers at the Virginia Experiment Station [2] also fed a group of dairy cows a ration high in energy but containing sufficient protein when the average digestion coefficients were used. This ration consisted of 9 pounds of corn

[1] Cornell Exp. Sta. Bul. 540.
[2] Va. Exp. Sta. Tech. Bul. 12.

meal, 2 pounds of wheat bran, and 40 pounds of corn silage. The nutritive ratio of the ration was 1 : 11.0.

The cows fed this ration consumed almost all their food and consequently obtained a large surplus of energy. However, ability to digest the nutrients decreased until the energy dropped to the requirements of the body for maintenance and milk production. Digestibility of the protein decreased 47 per cent; hence they were unable to maintain flesh and decreased in weight rapidly. The di-

FIG. 16.—Calf four months of age which has been deprived of roughage.

gestibility of crude fiber dropped 54 per cent, nitrogen-free extract 24 per cent, and fat 19 per cent. The average digestibility of all the nutrients in the ration was 23 per cent below the average coefficients as ordinarily given.

FEEDING WITHOUT ROUGHAGE

The cow's stomach is especially adapted for the handling of a large amount of roughage, and it is believed by practical dairymen that a ration must contain some of the coarse feeds, such as hay or silage. However, experiments conducted a number of years ago by

Miller[1] showed that dry dairy cows could be maintained for eight weeks on corn meal alone. He reported that the cows seemed contented after the first few days, but ceased to ruminate. At the Utah Experiment Station,[2] sheep and two-year-old steers were successfully fed on grain alone. The sheep were fed for almost six months, and the steers for almost eight months.

A more recent study at the California Experiment Station[3] shows that dairy animals can be grown to normal size when fed a ration devoid of roughage but supplied with vitamin A. Increase in body weight and milk production after first calving were subnormal because of insufficient nutrients. The appetites of the animals were excellent, but it was necessary to limit the ration in an effort to avoid serious bloat. The reproduction functions of the animals were normal, some producing as many as three calves without breeding trouble.

Seventeen lactations, more than 293 days in length, have averaged 6488 pounds of milk testing 3.19 per cent fat. The lowest production was 4460 pounds of milk, and the highest 9788 pounds. The cows ruminated at regular intervals, and the efficiency of digestion was found to be similar to that of animals receiving roughage. With the exception of bloat, no unusual symptoms were noted.

For some reason not yet fully explained, calves cannot successfully be grown when their ration is devoid of roughage. The California Station was able to grow calves to maturity by feeding them cod-liver oil and the ash from alfalfa hay, and also calcium carbonate and cod-liver oil. Other investigators have not been so successful. Calves fed milk and grain, or either one alone, develop normally for several months, and then gradually develop anorexia, lose weight, and eventually die. The blood of such animals shows low hemoglobin values, and general evidence of anemia also develops. This, however, can be prevented by the addition of iron and copper to the ration. Often tetany occurs with calves fed such rations. It has been shown that this is due to low blood magnesium. The Missouri Experiment Station,[4] however, fed a group of calves

[1] Feeds and Feeding, Henry and Morrison.
[2] Utah Exp. Sta. Bul. 21.
[3] Hoards' Dairyman 82 : 165.
[4] Mo. Agr. Exp. Sta. Res. Bul. 245.

on whole milk supplemented with iron, copper, magnesium, and cod-liver oil with the result that they died when about 12 to 13 months of age.

Although these studies are of experimental interest the question whether or not the animal could subsist upon grain alone is not so important as the economy of the practice. At ordinary prices of concentrates and hays, it is usually economical to feed roughages freely, at least to the medium-producing cows.

Feeding Roughages Alone

Dry cows can be maintained successfully on roughage alone, but when cows are producing milk such a ration is not high enough in net energy to give maximum production.

In a trial at the New Jersey Experiment Station [1] a ration consisting of 35 pounds of corn silage and 17½ pounds of alfalfa hay was compared with one consisting of about 9 pounds of concentrates fed with corn silage and corn stover. The latter ration produced 20 per cent more milk than the one without any concentrates.

In the irrigated alfalfa districts of the west, alfalfa is often the sole feed of dairy cattle. Although highest production cannot be expected with a ration such as this, yet sometimes the increase in production due to the feeding of concentrates may not be sufficient to pay for the extra feed. Under such circumstances it may not be economical to feed grain. Fairly high production is sometimes obtained when cows are fed roughages alone, but usually the production is not so heavy as when they are fed a grain ration. Several experiments [2] have been conducted which show the difference in production, the results of which are shown in Table XXVIII.

Even though the production is much less when the ration consists of roughage alone than when a full grain ration is fed, under certain conditions it may not be profitable to feed the grain.

Feeding from Restricted Sources

In extensive studies at the Wisconsin Experiment Station,[3] the physiological value of rations from restricted sources for dairy cows

[1] N. J. Exp. Sta. Bul. 204.

[2] U.S.D.A. Rept. and Nev. Agr. Exp. Sta. Bul. 140.

[3] Wisc. Res. Bul. 17 and Wisc. Res. Bul. 49.

TABLE XXVIII

Average Milk and Butterfat Production of Cows Fed Roughages Alone as Compared with Those Fed Roughage with a Grain Ration

Station	Average Yearly Milk Production				Percentage of Difference	
	Roughage Alone		Full Grain			
	Milk, lb.	Fat, lb.	Milk, lb.	Fat, lb.	Milk	Fat
Montana	13,657	478	17,852	620	30.7	29.7
Nevada	8,090	283	9,498	331	17.4	16.9
U. S. D. A.	11,375	402	18,009	621	58.3	54.5

was investigated. One lot of heifers were fed a ration consisting of feeds entirely from the corn plant, another from the oat plant, a third from the wheat plant. These rations were comparably balanced in regard to the supply of digestible organic nutrients. The heifers all grew fairly well, but those fed the oat and wheat rations failed to give birth to normal young. Most of them aborted, and the calves were born dead or very weak. The calves from cows fed the corn ration, however, were strong and vigorous. Further investigations [1] showed that the wheat and oat rations were lacking in a complete mineral mixture. When calcium was added to the ration the calves of the cows fed on the oats ration were normal, although in the case of the wheat plant this was not entirely successful. When alfalfa hay was added to the wheat ration in place of the wheat straw, the results were good for a while. Growth was normal and reproduction also was normal in the first gestation period, but weakness appeared in the second. The alfalfa introduced a better salt mixture, a little different protein mixture, and a more plentiful supply of vitamins.

Feeding with Lack of Minerals

Although feeding standards do not include mineral matter, it is necessary to have certain amounts of various minerals in the ration,

[1] Jour. Agr. Res. 10:175.

both for growth and for production. The standard does not include the minerals because, in most practical feeding methods, enough mineral matter is contained in the feed mixture.

Calcium.—A dairy cow may suffer from a lack of calcium in the diet without showing it. When an insufficient supply exists in the feed a cow can withdraw as much as 25 per cent or more from her skeleton. In an experiment at the Wisconsin Experiment Station[1] lime was withheld from the feed of a Holstein cow in milk. The cow weighed 1150 pounds and was fed for a period of 110 days. The outgo of lime was approximately 50 grams daily and

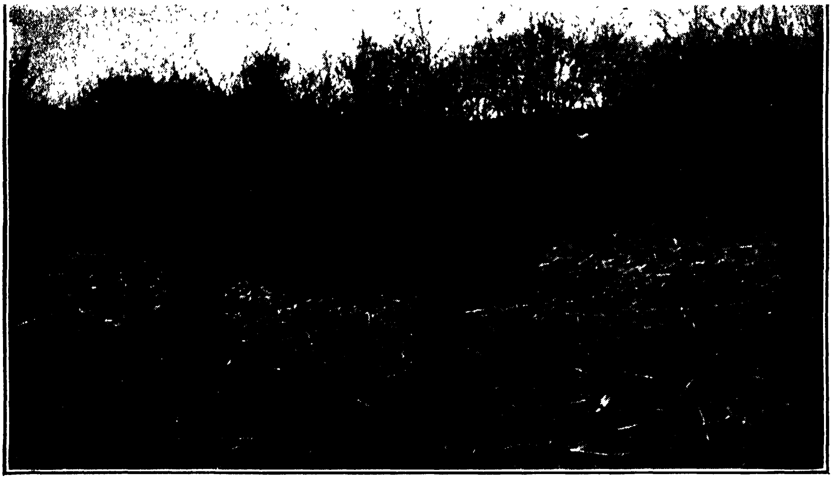

FIG. 17.—Results of mineral deficiency. This cow was so stiff she could scarcely walk, her joints made a noise as she moved, and she showed the typical abnormal appetite. (*Becker.*)

the intake only 25 grams, so that during the feeding period there was a loss of 2500 grams or 5½ pounds of lime. There was, therefore, a loss of about 25 per cent of the entire lime content of the cow's body without any decrease in the milk flow or the calcium content of the milk. The result was weakened bones that are easily broken. When the deficit is continued for some length of time the milk flow shrinks. The Florida Station[2] has reported that the addition of a calcium supplement and a small amount of legume hay to a ration of non-legume hay and grain resulted in a material in-

[1] Wisc. Res. Bul. 5.
[2] Fla. Exp. Sta. Bul. 262.

crease in milk yield in subsequent lactations, with an increase in the bone strength. In extreme cases animals may become emaciated and extremely weak so that they have difficulty in getting up and down.

Phosphorus.—Where the soil is very deficient in phosphorus the herbage growing on it is usually so low in this element that trouble is experienced in the feeding of cattle. Such conditions have been reported in various parts of the world.[1] The first symptom is usually a depraved appetite—an unconquerable craving to eat abnormal substances, such as wood, bones, clothes, earth, or ma-

FIG. 18.—Results of feeding bone meal to cow shown in FIG. 13. Note the difference in apparent stiffness of hind legs, and appearance of thrift of the animal. (*Becker.*)

nure. The cattle often become stiff in the joints. The symptoms usually follow a year of low rainfall. Cows in milk show the most severe symptoms, and young growing animals the next most severe. Milk production is lowered, and breeding trouble is often experienced. The addition of phosphorus to the ration of these animals results in complete recovery. Cows, however, may often suffer from a moderate deficiency of this mineral without showing many abnormal symptoms.

Iodine.—An insufficient supply of iodine in the ration results in goiter or "big neck" in dairy calves. The cows may appear

[1] Union S. Africa, Dept. Agr. Reprint 18 and Minn. Exp. Sta. Bul. 229.

normal but give birth to calves with goiter. Whether or not a lack of iodine in the ration affects milk production has not been ascertained.

Iron and Copper.—In some sections of the country,[1] where cows are restricted largely to forage grown on certain white and gray sandy soils and residual muck and peat soils not subject to overflow from more fertile watersheds, a trouble known as "salt sick" or nutritional anemia sometimes occurs. This is due to a lack of iron and copper in the feed. Under such conditions the cows become emaciated and fall in their milk flow. Young animals fail to grow normally; some two-year-old animals are little more than half normal in weight. Sexual maturity is delayed. The addition of iron and copper to the ration will effect a cure in a short time.

Feeding Rations Lacking in Vitamins

The two vitamins most likely to be lacking in the diet of the dairy animal are A and D. The others are either abundantly supplied in the common feeds or the dairy animal has no requirement for them.

Vitamin A.—Young growing animals have a very definite requirement for vitamin A in their diet. Without a sufficient supply of this vitamin, calves show the general symptoms of slow growth, general unthriftiness, scours, susceptibility to pneumonia, xerophthalmia, and even death. On ordinary diets where well-cured roughages are fed, these troubles will usually not be experienced. Evidence put out by the United States Department of Agriculture,[2] however, indicates that farm rations frequently fed to calves may be dangerously low in vitamin A; also that milk produced by cows fed hay which has lost its green color may be an unsafe source of vitamin A in the calf ration. Many calves show an unthrifty condition when from three to ten months of age, which can be largely overcome if they are fed a vitamin supplement or if abundance of well-cured alfalfa hay is supplied.

Although milking cows are not usually subjected to the trouble found with calves, still there can be little doubt that they some-

[1] Fla. Exp. Sta. Bul. 231.

[2] American Society of Animal Production Rept. 1932.

times suffer from the lack of vitamin A in their diet. Low vitamin A rations result in a milk low in this vitamin. The Texas Experiment Station[1] found that the vitamin A potency of butterfat of cows fed an insufficient amount of vitamin A decreased regularly during the period of lactation of the cow. At the beginning the milk contained from about 33 to 38 biological units per gram; then the amount decreased to 16 to 20 units in four weeks, and to 5 to 12 units at the end of five months, depending somewhat upon the ration of the cow. This decrease is probably due to the depletion of the storage of vitamin A. It has been found by several experiment stations that the feeding of a grain ration combined with a poor-quality hay results in a large proportion of premature dead or weak calves. If the ration is continued the cows die or become permanently sterile after about three years. The milk yield is usually only moderately reduced during the first year or two, but later becomes very markedly reduced in those cows which continue to breed.

Vitamin D.—The lack of vitamin D in the ration of closely housed calves results in a disease known as rickets, which is characterized by a decreased growth, stiffness, progressive emaciation, deformity of the bone, enlargement of the joints, slight paralysis of the rear quarters, and a bowed back. Low blood phosphorus, and a reduction of the total ash in the bone, are associated with this trouble. The trouble is not usually experienced in the summer when the calves are in the sunshine, or when they are supplied with an abundance of sun-cured hay of the kind and grade suitable for calf raising. The effect of low vitamin D on mature cows has not as yet been fully demonstrated, although it is probable that attention should be given to it.

Feeding by Means of a Self-feeder

When dairy animals are fed by means of a self-feeder in which feeds, grain, or roughage and grain are put before them so that they have access to them at all times, the animals are very extravagant in the amounts they consume. They consume much more feed than is required to meet their needs for maintenance and milk

[1] Texas Exp. Sta. Bul. 495.

production. They tend to become overweight and are not appreciably more productive. The health of the animals is not affected provided they are gradually accustomed to the method.

Growing animals consume a much larger proportion of grain than hay—so much so that they sometimes suffer from a lack of vitamins and come down with typical vitamin-deficiency symptoms.

Feeding Heavy Cottonseed Meal

Cottonseed meal contains a poisonous substance called gossypol which is said to vary with the climate and soil upon which the cotton is grown. In preparing cottonseed meal, the seeds are heated and the oil pressed out of them. In this process some of the gossypol is destroyed or changed chemically so that the meal is less toxic than the seed. This gossypol is said to be harmful to livestock, causing what is known as cottonseed meal injury. It has been recommended that only a limited amount of cottonseed meal be fed to dairy animals. This cottonseed injury is characterized by blindness, weakness, abortion with dead or weak calves, and eventually death.

Experiments have shown,[1] however, that such trouble does not occur when cottonseed meal is fed in addition to a good roughage. The same trouble has been experienced when animals were fed linseed oil meal, peanut meal, and soy-bean meal, with a poor roughage. It would seem therefore that cottonseed meal injury in dairy cattle was caused, not by the cottonseed meal itself, but by the lack of some substance carried by good-quality hay. Such roughages supply vitamins, especially vitamin A, and calcium, which is lacking in the cottonseed meal and other feeds. There seems to be no danger in feeding large amounts of cottonseed meal to dairy cows or to heifers if it is fed with a good-quality roughage. The heavy feeding of cottonseed meal[2] does not increase the susceptibility of heavy milk cows to udder infection, even when fed in large amounts with alfalfa hay.

[1] N. C. Tech. Bul. 39 and Jour. Dairy Sci. 13:478.
[2] U.S.D.A. Tech. Bul. 473.

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LECTURE XIV

SILAGE AND SILOS

For a great many years the advantage of preserving green crops for winter feeding has been recognized. As early as 1786,[1] history records that the Italians preserved green crops for their animals by storing them in pits under the ground. The French and English are known to have stored green crops a century and a half ago. We are not quite certain who should be given credit for the first

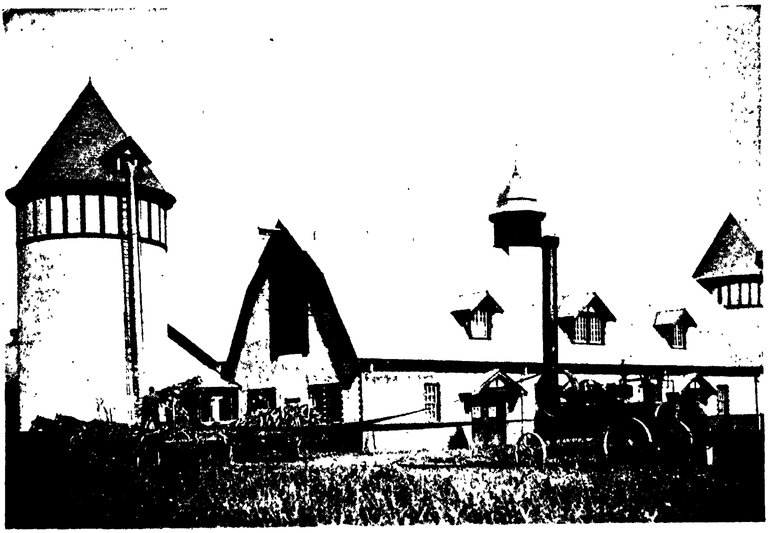

Fig. 19.—Filling a forty-foot silo.

silo in the United States, but it is probably Fred L. Hatch, who built one on his farm in 1873. For some time after this, however, farmers were slow to follow his example, and it is only in comparatively recent years that silos have been used extensively. Now they are to be found in all sections of the country, especially where dairying plays any large part in the farming industry. The use of

[1] U.S.D.A. Farmers' Bul. 32.

the silo to preserve feed for dairy cows is no longer considered experimental. It is a necessary part of the equipment of a profitable dairy farm, more especially where corn can be grown.

Advantages of the Silo

The advantages of the silo are:

1. More nutrients can be grown on an acre used for silage than an acre used for any other crop. This is shown in Table XXIX,

TABLE XXIX

Estimated Crop Yield, Digestible Nutrients and Milk Production per Acre

Crop	Pounds per Acre	Digestible Protein, lb.	Total Digestible Nutrients, lb.	4 Per Cent Milk, lb.
Corn silage	12,000	180	2472	3862
Alfalfa hay	4,000	424	2012	3142
Corn, ear and stover	3,850	135	1960	3062
Timothy hay	2,000	58	938	1462
Soy-bean hay	3,000	333	1518	2370

which gives the estimated crop yields, digestible nutrients, and milk production per acre of various crops.

It can be seen from this table that corn silage furnishes more nutrients per acre than any other crop. Alfalfa hay, its nearest competitor, produces much more digestible protein than the corn. These two crops supplement each other and should be fed together. If silage is grown, more milk can be produced per acre than with other crops.

2. There is less waste in silage than in crops handled in the dry state. More than one-third of the total food material in the corn plant is found in the stover. When corn is husked in the field and the stover is fed, there is still considerable loss. Table XXX from the Pennsylvania Experiment Station [1] gives the relative amount of

[1] U.S.D.A. Farmers' Bul. 578.

TABLE XXX

COMPARISON OF DIGESTIBLE MATTER FOUND IN THE EARS AND STOVER OF AN ACRE OF CORN

Constituents	Ears, lb.	Stover, lb.	Total Crop, lb.
Protein	244	83	327
Carbohydrates	2301	1473	3774
Fat	125	22	147
Total	2670	1578	4248

digestible matter found in the ears and in the stover of an acre of corn.

Even when corn is husked and carefully shocked, much of the food value is lost. In tests made by the Colorado Experiment Station, the losses due to curing corn in the field were considerable. Table XXXI shows these losses under different ways of handling.

TABLE XXXI

LOSSES DURING CURING OF CORN UNDER DIFFERENT METHODS

	Large Shock		Small Shock		On the Ground	
	Total Weight, lb.	Dry Matter, lb.	Total Weight, lb.	Dry Matter, lb.	Total Weight, lb.	Dry Matter, lb.
When shocked	952	217	294	77	186	42
After curing	258	150	64	44	33	19
Loss in weight	694	67	230	33	153	23
Per cent loss	73	31	78	43	82	55

When the corn is put into the silo, all the food material goes with it. The losses in the silo, due to fermentation, though considerable, are much lower than those that occur when the fodder is exposed in the field. It was found at the Wisconsin Experiment Station [1] that the losses in the silo due to fermentation and to spoilage

[1] Wisc. Exp. Sta. Bul. 59.

on top and sides and the losses of the juices averaged about 9.1 per cent. If crops are made into hay the losses because of unfavorable weather conditions are often considerable.

3. The crop can be harvested and stored more cheaply and with less labor. Because most of the work is done by machinery, more systematically, and on a larger scale, and the crop is handled but once, corn can be harvested and stored more cheaply in the form of silage than in any other form. When cut and put in the silo, the green feed takes up much less space than when stored loose.

4. Silage can be much more easily handled than the stover. The stover, unless shredded, is a very difficult feed to handle, whereas corn silage can be handled very easily.

5. Silage provides a succulent feed available at all times of the year. A succulent feed is necessary for the most economical production of milk, and silage provides it for winter feeding better than other feeds. The vitamins are better preserved and the silage makes a very palatable feed, which has a beneficial effect upon the digestive system of the cow.

Chemical Changes in Silage

One of the first changes which takes place in silage after it has been put into the silo is an increase in temperature. This increase is not great, however, if air is excluded; it amounts to about 15° F. near the bottom and about 35° F. near the top. When air gets into the silo, it may reach 125° F. If the silage is properly packed, this should occur only near the surface. If air is kept out the temperature seldom rises higher than 85° F. When the corn plant cell is broken it sets free food, upon which bacteria grow and thrive. Other conditions are also right for the growth of bacteria so that there is a great increase in their numbers. Frequently hundreds of millions of bacteria per cubic centimeter of the juice are found.

These bacteria, or enzymes secreted by them, work on the sugars in the corn and break them down into organic acids, principally lactic acid, acetic acid, and some ethyl alcohol. Since there is a destruction also of pentosans and starch during the fermentation process, it would indicate that these compounds are also in part converted into these products.

When the acid in the silage has increased to a certain degree, it inhibits the further growth of the bacteria and the action of the enzymes, and also checks the development of the putrefactive bacteria. Approximately 10 per cent of the dry matter, 25 per cent of the pentosans, and 25 per cent of the starch contained in the corn forage are changed as a result of four months' ensiling.

The fact that the legumes and grasses are low in sugar is one of the reasons why difficulty is sometimes experienced in preserving them. The amount of lactic acid developed during the fermentation process is shown in Table XXXII from results obtained at the Wisconsin Experiment Station.[1]

TABLE XXXII

LACTIC ACID CONTENT OF THE NON-VOLATILE ACID AT VARIOUS STAGES OF FERMENTATION

(Calculated for 100 grams of dry silage)

Age of Silage, days	Total Non-voltile Acid, grams	Lactic Acid, grams	Non-lactic Acid, grams
0	2.025	0.199	1.826
1	2.195	0.514	1.681
3	3.579	1.868	1.711
30	6.818	5.290	1.628
132	7.986	6.117	1.869

CROPS FOR SILAGE

A great many different crops are being used for silage; any green forage crop that contains a fair amount of sugar and gives a heavy yield per acre is satisfactory. Corn and the sorghums are the most satisfactory as they are heavy yielders and are the most easily preserved. Sunflowers have been used successfully, but where corn can be grown it is preferred. The legumes and grasses have been used with varying success as they are difficult to preserve when proper conditions are not maintained. The addition of mineral acids or molasses has greatly aided in the preservation of these crops.

[1] Wisc. Agr. Exp. Sta. Res. Bul. 61.

Sometimes some of the legumes are added with corn, and when this is done no trouble is experienced in the preservation. However, legumes usually do not ripen at the time that corn is ready to be harvested. Soy beans are often planted with the corn and cut and placed in the silo with it. This does not increase the yield obtained from an acre but the protein of the resulting silage is slightly increased.

Corn.—Corn is a standard and popular crop for silage in most dairy sections. It should be planted a little thicker than corn for grain, although it should not be planted so thick that it will not develop ears.

Early or Late Corn.—The variety of corn which a dairyman should grow for the silo depends upon several factors. The work at various experiment stations indicates that the variety which will yield the greatest amount of dry matter and which will mature to the late dough during a normal season is the best variety to grow. The value of the silage depends upon the dry matter that it contains. Since the late varieties usually contain more water than the early varieties, more will need to be fed to secure the same results. Table XXXIII gives the average yields of three types of corn, all planted and harvested at the same time, as found at the Connecticut Station.[1]

TABLE XXXIII

YIELDS PER ACRE OF SILAGE CORN

(Average of 5 years at Storrs)

Stage of Maturity	Green Weight, tons	Dry Matter, lb.	Per Cent Water
Early Corn (Hard dough)	12.4	6491	73.80
Medium Corn (Soft dough)	16.5	7218	78.09
Late Corn (Kernels just forming)	20.3	8064	80.16

If a dairyman has plenty of land, so that he can grow an abundance of hay and other roughages and still have room for corn, he should select a variety of corn that will mature early in his locality;

[1] Conn. Exp. Sta. Bul. 121.

one that will give a good yield of grain, and at the same time produce fairly good stalks. If, however, he is short of tillable land, he probably should select a larger variety, one that will not mature so early but will give him a larger tonnage per acre. This may not be so palatable or as nutritious as the other but will furnish succulent feed for the entire winter, which the smaller variety may not do.

Time to Harvest.—It is difficult to decide on the proper time to harvest corn for silage, but several factors must be considered. For the dairy farm it is wise to cut the corn when it is a little green rather than to risk its being frosted or becoming too ripe, because of the effect upon the carotene content. Experiments carried on by the United States Department of Agriculture have shown that corn ensiled when it was 90 to 100 per cent green resulted in a silage containing 111 to 156 parts of carotene per million. When the corn was ensiled when only 40 to 60 per cent of the leaves were green the resulting silage contained 35 parts of carotene per million. When it was ensiled after a slight frost there was practically no carotene (4 p.p.m.) in the resulting silage. On the other hand, it is not usually advisable to put the corn in the silo when it is too green as there is always considerable loss of moisture which carries with it considerable food nutrients. It may also become very acid if ensiled too green and not so palatable as that from corn not so high in water. It is best to harvest corn for silage when it has begun to glaze and, if a dent variety, when the dent is well developed and when the leaves are still green. Table XXXIV, based on work done at the New York Experiment Station,[1] gives the composition of the corn plant in its different stages.

It is not wise to let the corn become too well matured and dry. Even though it has been dry, if it is thoroughly wet it can be preserved satisfactorily but will be low in carotene.

Yield per Acre.—The amount of silage that can be grown on an acre of land varies with the soil, climate, care, and variety of corn. From 6 to 20 tons of silage can be grown to an acre, although the average is about the same as the yield of 35 to 50 bushels of shelled corn, which would be 6 to 10 tons of silage. In 1936 the average yield in the United States was 8.5 tons per acre.

[1] N. Y. Exp. Sta. 8th An. Rept.

TABLE XXXIV

CHEMICAL CHANGES DURING THE GROWTH OF THE CORN PLANT

Yield per Acre	Stage of Growth				
	Tasseled, July 30, lb.	Silked, Aug. 9, lb.	Milk, Aug. 21, lb.	Glazed, Sept. 7, lb.	Ripe, Sept. 23, lb.
Total yield	18,045.00	25,745.00	32,600.00	32,295.00	28,460.00
Water	16,426.00	22,666.00	27,957.00	25,093.00	20,542.00
Dry matter	1,619.00	3,078.00	4,643.00	7,202.00	7,918.00
Ash	138.91	201.30	232.15	302.48	364.23
Albuminoids	239.77	436.76	478.69	643.86	677.78
Crude fiber	514.19	872.93	1,261.97	1,755.85	1,734.04
Nitrogen-free extract	653.91	1,399.26	2,441.29	4,239.82	4,827.60
Fat	72.20	167.75	228.90	259.99	314.34

Corn Stover.—If, as occasionally happens, sufficient space is not available at silo-filling time for all the corn crop that it may be desirable to put in the silo, the corn stover may be put in later. Stover silage has the advantage that it is more palatable than corn stover; it prevents the loss of much of the stover; and it is much more convenient to feed. The stalks of the stover are put in the silo in the same way as the green corn, but in order to preserve it large quantities of water must be added. The amount of water added must be at least equal in weight to the stover. This can be done by turning a hose into the blower or by running water directly into the silo. It should be borne in mind that the ears have been removed so that it does not take the place of corn silage in food nutrients.

Sunflowers.—Sunflowers have been used successfully for silage in many of the states, especially in the arid regions. Their yield is a little higher than that of corn but they are not quite so high in nutritive value nor are they as palatable.

They can be planted in a row, the same as corn. The best distance to plant is about 10 inches apart in the row. They can be harvested in the same way as corn. Table XXXV from the West

Virginia Experiment Station[1] gives the analysis of sunflowers at different stages.

TABLE XXXV

ANALYSIS OF SUNFLOWERS AT DIFFERENT STAGES OF MATURITY

Stage Analyzed	Moisture, per cent	Ash, per cent	Protein, per cent	Fat, per cent	Fiber, per cent	Carbohydrates, per cent
Bud stage	80.75	1.53	1.41	0.55	5.48	15.76
Full blossom	86.69	1.59	1.21	0.50	3.90	10.01
Petals dropping	83.97	1.78	1.12	0.66	5.56	12.47
Dough stage	83.34	1.69	1.10	1.06	4.96	12.81
Mature	84.26	1.74	1.61	1.36	4.75	11.03
Silage	76.20	2.33	1.86	1.18	7.48	18.43

At the West Virginia Station,[2] the average yield for three years was 13.85 tons of green material per acre and 2.08 tons of air-dry material per acre, as compared with 11.79 tons green material and 2.91 tons of air-dry material per acre for a large variety of corn and 8.98 tons of green material and 2.57 tons of air-dry material per acre for a small variety of corn.

Sorghum and Kaffir Corn.—Both sorghum and kaffir corn make very good silage when put in the silo at the proper time. They are used in the middle west, especially where the rainfall is so scant that the corn plant is not a safe crop. In the south, where the soil has become impoverished by repeated planting of cotton and poor management, corn is not a profitable crop, but the sorghums will grow well in such territory, and will yield considerably higher tonnage than corn. The silage, however, is only about 75 per cent as efficient as corn silage in the production of milk. It should be cut when fairly ripe, otherwise the silage will be sour and unpalatable. If cut when too ripe, however, many of the grains will pass through the cow undigested. Kaffir corn silage and sweet sorghum silage are about equal in food value and palatability.

[1] W. Va. Exp. Sta. Cir. 32.

[2] W. Va. Exp. Sta. Bul. 204.

Legumes.—Such crops as clover, alfalfa, and soy beans have been preserved in a silo with more or less success. As already pointed out, it is often difficult to preserve these crops well since, on account of their lack of sugar, sufficient acid is not developed to keep down putrefying bacteria; but if the crops are allowed to dry a little before they are put in the silo they often develop into very good silage. Alfalfa, red clover, or sweet clover should be ensiled when they are in medium to late bloom; and soy beans should be ensiled when the seeds are just forming. Legume silage is not so palatable as corn silage, but cows eat it when they become accustomed to it. In rainy seasons, when legumes cannot be cured for hay, they are often put into the silo and used as a summer feed or kept as a winter feed as desired.

These crops are often mixed with the corn or sorghum at the time of ensiling and are then preserved very satisfactorily. When this is done the proportion recommended is one-third of the leguminous crop to two-thirds of the corn.

Grasses.—Numerous attempts have been made to ensile some of the finer grasses, as well as oats, rye, and wheat, with varying degrees of success. In general, it is better to feed these crops either in the green or in the cured state. It is difficult to keep them in a silo, although some success has been attained with some of them.

A. I. V. Silage.—Since difficulty often has been experienced in curing hays, experiments have been conducted in preserving the legumes and grasses in silos with the addition of dilute mineral acids. This system is known as the A. I. V. method, after its originator, A. I. Virtanen of Finland. It is used extensively in Finland, Sweden, and other northern European countries, and has been tried in a limited way in the United States.

Legumes and grasses, because of a lack of sugar, do not always preserve satisfactorily. The rapid formation of lactic acid, which occurs in well-preserved silage, although desirable from the standpoint of preservation, causes the destruction of a considerable amount of the food nutrients. In the A. I. V. method this is avoided by putting into the silage various mixtures of mineral acids (HCl, H_2SO_4, or other acids) so that the *p*H of the resulting silage shall be between 3.6 and 4. In this way the crop is preserved satisfactorily and considerable of the vitamin content of the green crop is

retained. Sometimes the silage becomes too acid to be palatable. It is usually advisable to feed some ground limestone or other form of calcium carbonate with it in order to neutralize any excess of acid which might be present.

Molasses Silage.—Another method of preserving green crops like the legumes and grasses is to add molasses at the time they are put into the silo. This increases the sugar content of the forage so that the bacteria will produce enough acid by fermentation to preserve the silage. From 20 to 80 pounds of molasses is run into the silo with each ton of green material, the amount depending upon the kind of crop and upon its stage of maturity. As little as 20 pounds per ton has been satisfactory with well-ripened soy beans, but 40 to 60 pounds is usual. The molasses is generally diluted with equal parts of water and run into the blower pipe or sprinkled over the top of the silage. A large part of the carotene content of the original green plant can be retained by this method.

Filling the Silo

The corn or other crops, when put into the silo, should be cut into small pieces not over ½ inch long, so that they will pack better and also so that they can be removed easily. The silage may be put into the silo either by means of a blower or by a carrier, in such a way that the leaves, stalks, and grain will be evenly distributed throughout the entire surface. Even distribution is best obtained by means of the jointed-pipe distributors. It is usually best to keep one reliable man in the silo to distribute the silage evenly. There is no need for tramping since the weight of the silage will pack it down sufficiently except towards the top, where it should be tramped, especially around the edges, so that it will not pull away from the wall, thereby admitting air and causing spoilage. If the corn is dry it is sometimes necessary to add water. Sufficient water should be added to make the moisture condition similar to that of green corn. The water may be run directly on to the silage or it may be turned into the blower. The latter method distributes it somewhat better.

After the silo is filled the first foot or two will spoil. In order that the loss may be less it is well to pull off the ears from the corn

that is to be put in the top, or to run some straw or other material on top. Sometimes oats are sowed on top of the silage, as with their roots they make a nearly air-tight surface.

Danger from Carbon Dioxide.—During the fermentation process, carbon dioxide, which is a poisonous gas, is given off. As this is a heavy gas it does not pass out if the doors are closed for some distance above the silage. Care should be taken, therefore, during the filling period when the machine has not been running for some time, not to enter the silo until the blower has driven off the dangerous gas.

Cost of Silage

If the haul is not too long and good machinery is available, the following figures by the Department of Agriculture[1] furnish a guide to the amount of labor and teams required to fill a silo efficiently:

1 man and 3 horses to bind the corn,
2 men to load the corn,
3 men and 6 horses to haul,
1 man to help unload,
1 man to feed the cutter,
1 or 2 men to work in the silo,
1 man to tend the engine if steam is used.

Total—10 to 11 men, 9 horses, and 3 wagons.

In a study[2] at the farm of the Bureau of Dairying, situated at Beltsville, Maryland, it was found that the cost of growing a ton of silage was $3.30. This included labor, interest on land valued at $100 per acre, depreciation on machinery, seed, and commercial fertilizer. The yield of corn was 10.19 tons per acre. The cost of filling the silo was found to be $1.44 per ton, including the labor, supplies, depreciation, and interest on machinery and equipment. Adding to this the depreciation of the silo which, it is figured, amounts to 24 cents per ton, makes a total of $4.98 per ton for silage when stored in the silo. This cost varies with different farmers and in different localities owing to difference in yields and methods, but it should not depart greatly from these figures.

[1] Farmers' Bul. 556.
[2] Farmers' Bul. 578.

Feeding the Silage

Silage and other succulent feeds are excellent for dairy cows, especially because of their palatability and slightly laxative effect. For these reasons cows will consume large amounts of nutrients without any harmful effects, and will as a consequence produce more milk than when fed feeds less palatable. Succulent feeds, however, are not absolutely necessary for high production. When cows are fed a good legume hay, with some other good hay for variety, and are given access to an abundant supply of water, they will produce just as much milk as when fed silage. If the roughage is not of the best quality, however, cows will usually milk better when silage is included in the ration.

The amount of silage fed to cows depends upon the amount available and also upon the size of the cow; usually it ranges between 20 and 40 pounds. The general rule is to feed it at the rate of 3 pounds of silage and 1 pound of hay for each 100 pounds of live weight. Experiments have shown that 3 pounds of silage can be substituted for 1 pound of hay and fed with about equal results. If a limited amount of silage is available, the quantity can be cut in half and the hay increased without affecting milk production. Silage can be fed as the sole roughage provided sufficient protein and minerals are given in the grain mixture. Cows will consume up to 6 pounds per 100 pounds live weight when fed in this way.

Construction of Silos

Size of Silo.—One of the most common mistakes in the building of silos is to give them over-large diameters, which make it impossible to feed the silage fast enough to keep it from spoiling. Each day 2 to 3 inches should be removed from the surface of the whole silo in order to preserve the silage. A further advantage of a silo with a small diameter and a greater height is that the silage will be more compressed and less air will be admitted. If small quantities of silage are needed for supplementary feeding, as, for instance, for late summer feeding, it is well to provide a separate and smaller silo.

The diameter of the silo will depend upon the size of the herd; Table XXXVI shows the proper size of the silo relative to the length of the feeding period and the size of the herd.[1]

TABLE XXXVI

SIZE OF SILO

Number of Cows in Herd	Feed for 180 Days			Feed for 240 Days		
	Estimated Tonnage of Silage Consumed, tons	Size of Silo		Estimated Tonnage of Silage Consumed, tons	Size of Silo	
		Diameter, feet	Height, feet		Diameter, feet	Height, feet
10	36	10	25	48	10	31
12	43	10	28	57	10	35
15	54	11	29	72	11	36
20	72	12	32	96	12	39
25	90	13	33	120	13	40
30	108	14	34	144	15	37
35	126	15	34	168	16	38
40	144	16	35	192	17	39
45	162	16	37	216	18	39
50	180	17	37	240	19	39

Walls.—In the building of a silo, the first essential is a tight wall that will exclude air and moisture and at the same time not absorb moisture from the silage. When the moisture is taken up by the wall the absence of water from the outer layer of the silage makes the proper fermentation impossible, and molding takes place. Silos built of stone or porous cement should either be washed with a cement on the inside or given a treatment of tar or some sort of waterproofing material.

It is necessary also that the walls be smooth, with no ledges or projections. Wherever there is a ledge, settling does not take place uniformly, and air enters, causing the silage to spoil.

A further essential of the wall is that it be strong enough to withstand the pressure of the silage. It should also be durable enough to last for some years.

[1] Mo. Exp. Sta. Bul. 133.

Foundation.—The foundation should be well constructed, for there is a great weight in the silo. Usually foundations are of concrete. It is best also to have a floor in the silo, but this is not absolutely necessary. A floor of concrete keeps the rats from digging in and is easy to clean. It is often desirable to provide a drain in the bottom of the silo. This may be kept plugged except when the silo is to be cleaned or when water has got into it. Sometimes in very wet seasons, and when the corn must be cut green, the moisture is very great; a drain may then be desirable.

Roof.—A roof is desirable but not absolutely necessary. It prevents snow and rain from entering the silo. These, especially the snow, often make the silage unpleasant to handle. A roof also reduces the freezing to some extent. The greatest advantage of the roof, however, is that it protects the silo itself so that it will last longer.

Doors.—The door of the silo should be air-tight and flush on the inside. Properly fitting doors are one of the essentials of a good silo. If the doors do not fit tightly air will get in and spoiling will result.

Shape.—With regard to shape, practically the only silos now in use are round. They are built in this form because in a square silo the corners would be difficult to fill. Besides, the round silo is stronger.

Types of Silos

There are many types of silo-building materials, most of which will prove satisfactory as far as keeping the silage is concerned. However, the cost and durability of the various kinds differ considerably.

Stave Silo.—Perhaps no other type of silo in use in the country has met with such favor as the stave silo. It is cheaper than most other styles and can be easily constructed. It gives very satisfactory results if properly made and cared for. Only good material should be selected for a stave silo. The kind of wood to be chosen may be judged by the following suggestions from the Iowa Experiment Station.[1]

"(*a*) *Redwood* is one of the conifers which is generally accepted

[1] Iowa Exp. Sta. Bul. 141.

as having the best qualities of any wood used in silo construction. Redwood trees are very large and the lumber uniform. In buying redwood silos, a very good grade of practically clear and full-length staves may be secured. The shrinkage and swelling due to moisture are less than in any other woods. This is quite an advantage on account of the shrinkage which occurs when silos are empty. A stave silo built of this material after eleven years of use was examined carefully. Every stave was gone over with a knife and not a soft spot was found anywhere.

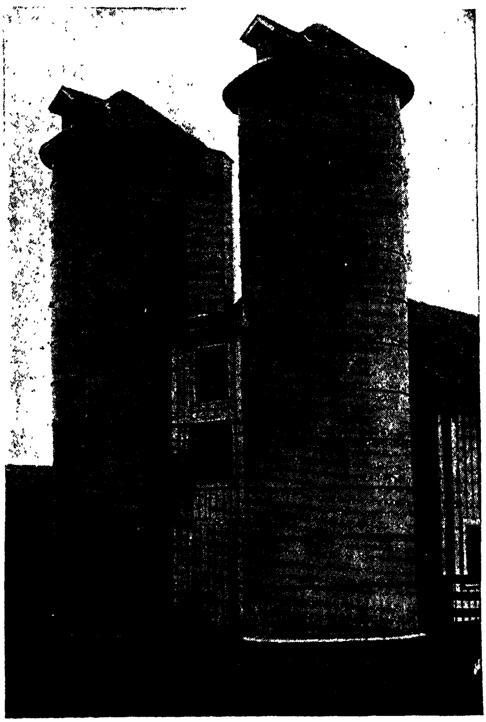

FIG. 20.—Twin stave silos.

"(*b*) *Cypress*, being quite similar to the quality and characteristics of white cedar, is well adapted to the building of silos. Only a clear or good sound-knotted stock should be used. More cypress than any other kind of wood is used for water tanks in the Middle West.

"(*c*) *Oregon Fir* is an excellent wood for stave silos, as it can be secured in full-length staves and is quite clear and uniform. With reasonable care and a foundation high enough to raise it above moisture, a silo with fir staves will last for a long term of years.

"(*d*) *Tamarack*, or larch, is very similar to the best hard pine, but where equal grades of each are obtainable it is best on account of its greater durability.

"(*e*) *White Pine*, if free from loose or large knots, makes a very good silo. The staves cannot usually be obtained in full length for a desirable height of silo.

"(*f*) *Long-leaf yellow* or hard pine is the strongest and stiffest of all pines, and if a choice grade is secured, it makes a very good silo at a reasonable price. It shrinks a little more than the woods previously mentioned, but the hoops of any stave silo should be tightened when the silo is empty."

Monolithic Concrete Silo.—Concrete silos are now being used quite extensively in this country. They require special forms in

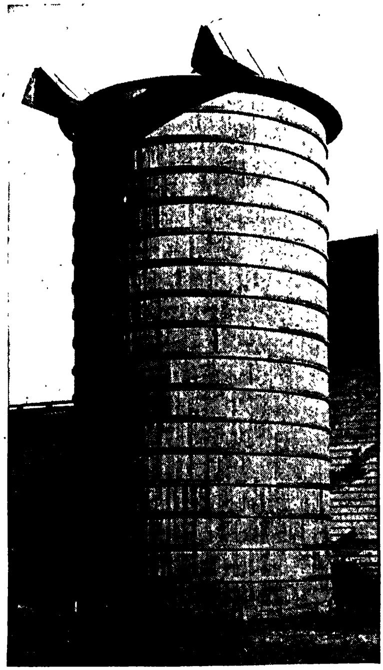

FIG. 21.—A wooden hoop silo.

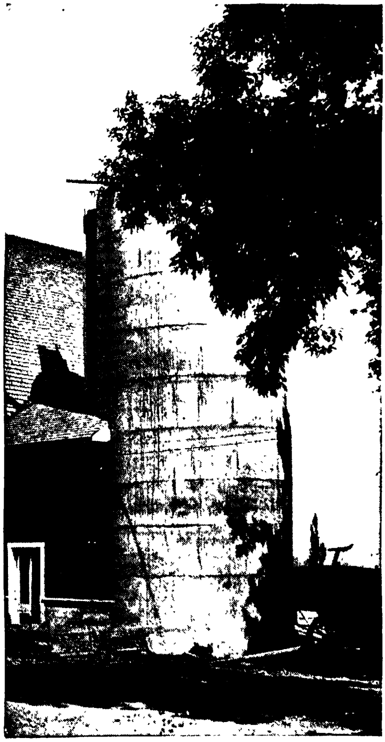

FIG. 22.—A monolithic concrete silo.

their construction but these can easily be made by following directions put out by the Department of Agriculture.[1] In some of the earlier silos of this type, care was not taken to reinforce the walls sufficiently, and as a result some of them burst. With proper reinforcement it is not difficult to make them strong enough. A common criticism is that the acid attacks the cement, and that it will even-

[1] Farmers' Bul. 589.

tually destroy the wall. It is true that the acid may attack the cement to some extent, but the washing of the walls on the inside with cement plaster, or a thin application of tar, will maintain a tight surface. The cement silo has an important advantage over the wooden silo: it cannot be destroyed by fire or wind and if properly constructed will last indefinitely.

Hollow-wall Concrete Silo.—There are two types of hollow-wall concrete silos, known respectively as the hollow-cement-block silo and the hollow-wall silo. It is claimed that the contents are less susceptible to freezing in these silos than in the solid-wall silos. A further advantage of the cement-block silo is that it can be constructed more easily as no forms are necessary.

Hollow-tile Silo.—This type of silo has become very popular in many sections of the country. The advantages are that a strong, smooth wall can be obtained and no forms are necessary. It preserves the silage as well as other types and makes a very satisfactory silo.

Brick Silo.—In most sections brick are too expensive for silos, but when they can be secured near by at a low price they may be used if properly reinforced. The inside of the silo should be coated with cement plaster.

Metal or Steel Silo.—The metal or steel silo has been reported to give satisfaction. It can be made air-tight, requires little attention, and preserves the silage satisfactorily.

Trench Silos.—The trench silo has been used as an emergency silo with good results. A trench is dug in the ground not more than 8 feet nor less than 5 feet deep and of a width so that about 1 foot of silage is removed every 5 days to prevent spoilage. The length depends upon the amount of silage to be preserved. At least 6 feet should be available for each month of feeding, so that if it is desired to feed 7 months, it should be 42 feet long. A roof is sometimes put on but is not necessary. The corn is cut and put in the same as in ordinary silos, but it must be well packed; this can be done by driving a team or tractor over it. A foot of straw should be cut and put on the top to prevent the silage from spoiling.

Emergency silos made of slats similar to picket fences, and lined with a heavy reinforced paper, have given satisfactory results.

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LECTURE XV

HAY AND HAYMAKING

Hay is the harvested, unthreshed herbage of those kinds of forage plants which have a recognized feed value, and which are not coarse and woody, and which do not contain more than 35 per cent of foreign material.

The importance of good hay for winter feeding can hardly be overestimated. Dairy cows with their large feed capacity are capable of consuming large quantities of rough feed, and their digestive systems are specially adapted to the digestion of such feeds. Hay can be easily grown on most farms in the United States and hence is a very economical feed, since home-grown feeds are usually much cheaper than purchased feeds. Pasture makes an ideal feed for dairy cows during the summer, but some of the forage crops must be dried for use during the winter when pasture is not available. If well cured and preserved they make one of the most economical feeds that are available at that time. Hay can be fed in conjunction with silage and grain or alone with grain. Occasionally it is fed as the sole feed, but dairy cows cannot consume a sufficient quantity of hay alone for maximum milk production.

Kinds of Hays.—Hays are divided into two groups, namely, legume and non-legume. Although legume hays are generally superior to the non-legumes in the amount of protein, in the mineral and vitamin content, and in palatability, this difference may not always exist as a great deal depends upon the soil on which the hays are grown. A grass hay, for instance, grown upon a soil that is rich in nitrogen, lime, and phosphorus, cut early, and well cured, may be superior in many respects to a legume hay not so well grown and cured. The fact that a hay is legume is not always a sign that it is a good hay. Other factors must be considered to determine the difference between good hay and poor hay, such as time of cutting, curing, and storing, and the kind of soil upon which it is grown.

Legume Hays.—Good legume hay has many characteristics that make it of special value for dairy cattle. Some of them are as follows:

1. With the exception of corn silage, legume hay will produce more digestible nutrients on a given area than any other crop. This is especially true of alfalfa, which will yield two or three crops during the season. Other legumes yield heavily but not so much as alfalfa.

2. More digestible protein can be grown on an acre with legume hay than with other common crops. This is especially important

FIG. 23.—A field of soy beans ready to be harvested for hay.

because of the fact that most of the other home-grown feeds are comparatively low in protein. The non-legumes and cereal grains are low in protein, so that legumes supplement them in an excellent way. Furthermore, the protein of legumes is of excellent quality. Heifers will grow normally when all the protein comes from the alfalfa plant.

3. Well-cured legume hays are higher in the vitamins necessary in the nutrition of dairy cattle than any other of the common feeds. They are particularly rich in carotene, the precursor of vitamin A, and may contain considerable vitamin D. They are also a rich

source of vitamin E and vitamin G. Non-legume hays when well cured, and corn silage, may also contain considerable amounts of these vitamins, but the cereal grains are low in them.

4. The legume hays are especially rich in calcium. In fact, the dairy cow must depend largely on the legume for her calcium supply, as the non-legume hays, silage, and grains are all low in this element. The legume hays are only moderately rich in phosphorus, the amount depending upon the amount in the soil upon which they are grown. They are usually considered a fair source of this element.

5. Good legume hay is palatable, adds the necessary bulk, and has a good physiological effect upon the digestive system of the cow. With the possible exception of corn silage, no winter roughage is better liked than good legume hay.

6. Legume hay is easily grown, requires no cultivation, and keeps the ground covered, thus preventing erosion better than the cultivated crops. Alfalfa hay continues for several years with one seeding. Sometimes there is difficulty in getting a good stand of alfalfa as the soil must be especially prepared for such a crop, well drained, and not too acid. Soy beans and some of the other legumes will grow on soil where the acidity is higher than is required for growing alfalfa.

The principal legume hays grown in the United States are alfalfa, clover (red, mammoth red, alsike, crimson, and sweet), soy bean, cow pea, and lespedeza. These crops have been discussed in a previous lecture.

Non-legume Hays.—Grass hays, such as timothy, red top, blue-grass, sudan grass, and sorghum, are usually not as good feeds for dairy cattle as the legumes. They are, as a rule, less palatable, and contain less protein, mineral matter, and vitamins than the legume hays. However, if they are harvested early and are properly cured, they may be equal to legume hay in palatability, and their protein content may be not far under that of ordinary legume hay. If the soil upon which they are grown has been fertilized with a high-nitrogen fertilizer, the protein content will be greatly increased.

Grass hays have been very popular over most of the United States, even though legume hays have many advantages over them. The reason for this is the ease with which they can be grown and cured.

Grain Hays.—Considerable hay is made with the small cereals, such as oats, barley, wheat, and rye. These make fair hay if cut early when the grain is in the milk stage, and compare very favorably with the grass hays. They are low in protein and in minerals, however, and are adapted more for an emergency hay crop than for a regular hay crop.

Mixed Hays.—Many farmers grow a legume hay and a non-legume hay in combination, calling it mixed hay. Some of the most common mixed hays are clover and timothy, alfalfa and timothy, soy beans and sudan grass, oats and peas, and oats and vetch. Any other combination in which a legume and a non-legume is grown would be called a mixed hay. The composition of such hay will depend upon the proportion of each kind of hay which it contains. It is usually cut early, and hence the non-legumes are higher in protein than when cut at the ordinary time. The practice of growing mixed hay is to be recommended where difficulty is experienced in getting a stand of legume hay. It can be made into high-quality hay.

Grades of Hay.—Good well-cured hay makes an excellent feed for dairy cattle, but much of the hay produced in the United States cannot be classified as good hay. As a consequence it does not make as good feed as if it were well cured. This poor hay is due in part to cutting when the hay is too ripe, and in part to unfavorable weather conditions at the time of cutting, and to improper curing, harvesting, and storage. Furthermore, until recently the real difference between good hay and poor hay was not fully understood. The Department of Agriculture [1] has set up grades on hays which have done much to educate the producers of hay to the desirable factors.

Hays for which there are standards are divided into nine groups as follows: Group I, alfalfa and alfalfa mixed hay. Group II, timothy and clover hay. Group III, prairie hay. Group IV, Johnson and Johnson mixed hay. Group V, grain, wild oat, vetch, and grain-mixed hay. Group VI, lespedeza and lespedeza-mixed hay. Group VII, soy bean and soy bean-mixed hay. Group VIII, grass hay. Group IX, mixed hay.

[1] U.S.D.A. Handbook of Official Hay Standards.

The grades of alfalfa and alfalfa-mixed hay depend upon the leafiness, percentage of green color, and maximum percentage of foreign matter. The grades of timothy and clover depend on green color and maximum percentage of foreign material. Grades for the other groups have been worked out in a similar manner. The standard grade requirements for alfalfa and alfalfa-mixed hay and for timothy and clover hay are stated in Table XXXVII. Because of

TABLE XXXVII

GRADE REQUIREMENTS FOR ALFALFA, ALFALFA-MIXED, AND TIMOTHY AND CLOVER HAY

U. S. Grade Number	Leafiness of Alfalfa and Alfalfa-mixed (per cent leaves)	Percentage of Green Color		Maximum Percentage of Foreign Material	
		Alfalfa and Alfalfa-mixed	Timothy and Clover	Alfalfa and Alfalfa-mixed	Timothy and Clover
1	40 or more	60 or more	45 or more	5	10
2	25 or more	35 or more	30 or more	10	15
3	Less than 25	Less than 35	Less than 30	15	20

this grading, much of the hay is now being purchased upon grade and as a result the quality of hay has been improved.

Effects of Curing on Quality of Hay.—Hay should be cured in such a way as to preserve the leaves, preserve the green color, and drive out sufficient moisture so that it will keep well in storage.

Importance of Leaves.—The leaves on some of the hay crops, such as alfalfa, soy beans, and other legumes, are very important. In the alfalfa plant the leaves make up about 47 per cent of the crop, but their protein content is 141 per cent higher than that in the stems. Twenty-eight pounds of alfalfa leaves contain as much protein as 100 pounds of stems. The leaves of alfalfa are also much higher in calcium and in vitamins than the stems, and they are much more palatable. Grizzard[1] found that the leaves of alfalfa were almost three times as high in calcium and one and one-half times as high in phosphorus as the stems. Snell[2] has given the

[1] Jour. Am. Soc. Agron. 27 : 81.

[2] La. Agr. Exp. Sta. Bul. 257.

chemical analyses of the stems and leaves of soy-bean hay as shown in Table XXXVIII. From this table it can be seen that more than

TABLE XXXVIII

CHEMICAL COMPOSITION OF TWO SAMPLES OF SOY-BEAN HAY

	Leaves		Stems	
	Sample 1, Per Cent	Sample 2, Per Cent	Sample 1, Per Cent	Sample 2, Per Cent
Part of plant	55.39	64.02	44.61	35.98
Crude protein	19.37	21.07	5.18	7.33
Ether extract	3.48	2.38	0.87	0.76
N-free extract	35.34	35.37	28.22	26.51
Crude fiber	22.11	21.38	49.64	49.18
Ash	9.47	9.80	5.46	5.88
Water	10.00	10.00	10.00	10.00

half of the soy-bean plant is in the leaves and that it contains very much more than half of the food value, being higher in protein, ether extract, nitrogen-free extract, and minerals. The stems are much higher in crude fiber.

Unless care is taken in curing these crops much shattering will result, and many of the leaves will be broken off. In this way a considerable part of the protein, ether-extract, nitrogen-free extract, and ash will be lost, and the resulting hay will be considerably lessened in food value.

Importance of Greenness.—The green color of the leaves indicates the amount of carotene, the precursor of vitamin A, that is present. The importance of this element, not only for the nutrition of the animal but also for its value in the milk produced by dairy cows, has already been mentioned. Carotene is easily oxidized, probably as the result of an enzymatic process not caused by the sunlight but affected by it in an indirect way by producing temperatures which accelerate enzymatic action. The Department of Agriculture has calculated the carotene content of various feeds including the different grades of alfalfa hay and timothy hay, as shown in Table XXXIX. It can be seen by this table that there is

TABLE XXXIX

THE CAROTENE CONTENT OF ALFALFA AND TIMOTHY HAY *

Feed	Determination Number	Water, per cent	Carotene per Gram of Dry Matter		
			High Gamma	Low Gamma	Average Gamma
Fresh green alfalfa.....	5	79.6	412.0	267.0	326.0
U. S. No. 1 alfalfa hay.	6	8.6	117.1	33.6	60.6
U. S. No. 2 alfalfa hay.	2	8.6	16.3	13.7	15.0
U. S. No. 3 alfalfa hay.	2	8.6	12.4	1.0	6.7
U. S. No. 1 timothy hay	3	11.6	24.5	9.0	18.9
U. S. No. 2 timothy hay	1	11.6	8.0	8.0	8.0
U. S. No. 3 timothy hay	2	11.6	10.7	1.6	6.1

* U.S.D.A. Yearbook of Agriculture (1935).

considerable loss of carotene in the curing of hay, even under good conditions; but, with the exception of pasture and green feeds, well-cured hays are the best source of this compound. It must be realized, however, that both hay and pasture are subject to great variations in their carotene content.

Vitamin D Content of Hay.—Hay when it is first cut contains very little if any vitamin D, the antirachitic vitamin. The ergosterol in such hay, however, when cured in the sun, changes into vitamin D. Sun-cured hay, with the exception of direct irradiation of the animal herself with the ultraviolet light of the sun's rays, is about the only natural source of this vitamin available to the cow. The antirachitic potency of dried roughage depends upon the intensity of the sunlight, the length of exposure, and the amount of ergosterol in the plant.

It has been shown [1] that hay cured away from the sunlight contains no appreciable amount of vitamin D, but hay exposed to the sunlight for some time may develop considerable antirachitic potency. Even sun-cured timothy has been found to contain considerable vitamin D. Two pounds per day of such hay will prevent rickets in growing calves until they are about one year of age.

[1] Jour. Agr. Res. 46: 235.

The legume hays are usually considered better sources of this vitamin than the non-legume hays.

Since the vitamin D potency of hay depends upon its exposure to sunlight, and since the sunlight seems to accelerate the destruction of the carotene in hay, it can be seen that it is a difficult process to cure and handle hay in such a way as to obtain the maximum amount of both of these factors. Longer exposure to sun has other deleterious results, such as loss of leaves, so that the quality and carotene content of the hay is usually given first consideration in the curing of hay.

Effect of Soil on Quality of Hay.—That the soil has an effect upon the hay grown on it has been fully demonstrated.[1] In fact, some soils are so deficient in certain minerals, such as calcium and phosphorus, that the herbage grown upon it will not support normal well-being in dairy cattle. Alfalfa grown on soils low in phosphorus will be low in that element. Grass hays will be affected also by the amount of calcium and phosphorus in the soil. The amount of protein in hays can be materially increased by adding a nitrogen-containing fertilizer to the soil. High-quality hay can be produced then only upon soils that are rich in available minerals.

Time of Cutting.—One of the common mistakes in making hay is to let the hay become too ripe before cutting. Hay cut early is higher in protein, is lower in crude fiber, contains more of the vitamins, is more palatable, and will shatter less than that allowed to become ripe.

It is usually recommended that alfalfa hay should be cut when it is one-fourth to one-third in bloom, after which time the protein decreases and the crude fiber increases. It is wise not to cut when too young lest the stand be weakened. Clover hay should be cut when it is two-thirds to full bloom. The total yield may increase after this but the protein content decreases, as do the digestibility and palatability.

Soy beans are best fitted for hay when the seeds are about one-half developed. If the crop is cut earlier the percentage of protein is higher, but the total yield is not so large and the difficulty of curing is much greater. If cutting is delayed beyond this, the stems become hard and woody, and many of the leaves are lost.

[1] Jour. Am. Soc. Agron. 27: 81.

Timothy is usually left until it is quite ripe, when it loses much of its food value. Experiments have shown that the protein of timothy decreases rapidly after it starts to bloom, as do its palatability, its digestibility, and its vitamin content. Timothy should be cut before it comes in full bloom, and should never be allowed to ripen.

All grass hays make much better feed for dairy cattle if they are cut when they first begin to come into bloom. The small grains, when cut for hay, should be cut when the grain is in the milk stage and before they begin to harden.

FIG. 24.—Harvesting hay in Holland.

Curing the Hay.—In curing hay it is necessary to keep it from becoming bleached by the sun and rain, to preserve the leaves from shattering, and at the same time to drive out sufficient moisture so that it will keep in the barn without heating and spoiling.

There is perhaps no best time to cut hay, although it should not be cut until the dew is gone. It should then be allowed to lie in the swath until it is thoroughly wilted. After wilting, and before the leaves become dry and brittle, it should be raked in windrows. Care should be taken not to rake the hay when it is so dry that the leaves will shatter. It is best to rake it when there is some dew. Usually small windrows are to be preferred to large ones. The length of time that hay should remain in the windrow depends upon the

weather conditions and the crop. Soy-bean hay is harder to cure than alfalfa, clover, or the grass hays, since their stems are larger and harder to dry out. Hays are often put up in cocks to protect them against rain, but they should be spread out again as soon as possible. The grass hays are easier to cure than the legumes as the leaves are not so easily broken off. Care must be taken with all hays, however, in order to preserve them properly.

Hay when ready to put into the barn or stack should not contain more than 25 per cent moisture, and preferably not more than 22 per cent if it is to be stored in large amounts. If there is more moisture than this, it will heat and fermentation will take place, causing loss of nutrients. In case of threatening rain, one or two loads of hay may be put into the barn before it reaches the desired dryness, if care is taken to keep it well spread out so that it is not more than two or three feet deep at any place, and not covered over with other hay before it has had time to dry.

Mechanical Curing.—Because of uncertainty of weather conditions mechanical curing of hay has been tried in many places. By this method the hay is hauled directly from the field just after being cut. It is then usually chopped as it enters the dryer where it passes over hot drums which drive off the moisture until it contains from 10 to 15 per cent. The hay is then either sacked or blown into the storage mow. The advantages of this method are that weather conditions interfere little with the operation; it eliminates the loss due to shattering of leaves; there is less chance of its heating and spoiling in the mow; its carotene content is preserved; and it is generally a little more palatable than ordinary cured hay. Hay cured in this way has very little, if any, vitamin D, as it is not exposed to the sun's rays. The cost of such machines has made them prohibitive except on large farms where they can be used enough to pay for their cost and operation.

Hay Silages.—In order to preserve hay without interference from the weather, the silo has frequently been used. As already pointed out, silage made from such forages lacks sufficient sugar to preserve it satisfactorily without special care. Special methods have been devised, however, by which it is preserved successfully, for example, A. I. V. silage and molasses silage. These have been discussed in a previous lecture.

Storage of Hay.—Hay is usually stored loose in mows or in stacks. When stored in the barn it is important that the hay be well distributed. When put in with a hay fork too much should not be allowed to drop in one pile; otherwise it may heat and spoil. Many people chop up the hay as it comes from the field with a hay cutter similar to a silage cutter, and blow it into the mow. Such a method has the advantage that considerably more hay can be stored in a given space; and furthermore, it is easier to remove as it is not bound in like loose hay. Care must be taken, however, that the hay is well dried, or it is likely to heat badly. There is some danger of spontaneous combustion with hay stored in this way unless it is more thoroughly dried than when stored loose.

Brown Hay.—Sometimes because of very unfavorable weather conditions good hay cannot be obtained by the ordinary methods of curing, and it is then made into what is known as "brown hay." The hay is allowed to dry until about 50 per cent of the moisture has been removed, and then it is packed in a stack or in piles. Fermentation takes place and the hay becomes very hot, but the temperature should not exceed 175° F. The heat dries out the hay. During fermentation much of the dry matter is oxidized so that it may lose as much as 40 per cent of the total dry matter. Digestibility is also decreased. The hay, however, is often quite palatable, but because of the great waste in dry matter the method is not recommended. The vitamins are probably destroyed in the process of fermentation.

Danger from Spontaneous Combustion.—If hay is put in the mow or stacked when it contains too much moisture, it may ferment very rapidly, releasing a large amount of heat. If it is allowed to continue for a month or six weeks, the temperature may rise to 300° F. to 400° F., when spontaneous combustion may occur and the hay burst into flame. This may be prevented by taking care not to store hay with an excessive amount of moisture; or, if this is unavoidable, to distribute the hay well, not allowing it to become packed. Leaks in the roof, unknown to the owner, sometimes cause this trouble.

Feeding Hay.—Since hay is one of the cheapest winter feeds produced on the farm, and since dairy cows are well adapted to its consumption and digestion, it should be fed in large amounts. The

amount that a dairy cow will eat, however, depends upon the quality of the hay and the amount of other feed.

Because of its bulky nature, hay alone cannot be consumed by cows in sufficient quantity to produce maximum amounts of milk; it is usually fed with some other more concentrated feed. Cows have produced fairly large amounts of milk and butterfat when fed on legume hay alone, but not as much as they would have produced if they had been fed some grain. Some dairymen maintain that it is more profitable to feed the cows large amounts of roughage and small amounts of grains, even though the maximum amount of milk is not obtained, because of the lower cost of the roughage as compared to the grain. The right proportions depend upon several factors. When the price of milk is very low and the price of grain is high, there seems no question but that it might be more economical to feed a ration consisting largely or entirely of roughage. But if the price of milk is high and the cost of grain is low, it usually is more profitable to feed a full grain ration. Ordinarily a moderate grain ration with fairly heavy roughage feeding is to be recommended.

Legume roughages and corn silage go well together in making a dairy ration. The hay adds protein and the silage adds succulence. Both are palatable and produce high yields per acre. Legume hay, however, can be fed satisfactorily as the sole roughage, and when water is available at all times it will produce just as much milk as when fed in conjunction with corn silage. Under this condition it is necessary to feed more hay. One pound of hay is equivalent to about 3 pounds of silage in digestible nutrients, but the legume hay contains considerably more protein.

The general rule for feeding hay is to feed all that the cows will clean up. As stated before, the amount that they consume depends upon the quality of the hay and the amount and kind of other feeds. When fed with corn silage and a full grain ration, they will consume about 1 pound of hay and 3 pounds of silage for each 100 pounds of live weight.

When fed without silage but with a full grain ration, they will consume about 2 pounds of hay to each 100 pounds of live weight. As noted before, about 1 pound of hay is substituted for 3 pounds of silage.

When fed without silage but on a limited grain ration, cows will consume as much as 3 to 3.5 pounds of hay to each 100 pounds of live weight.

These consumption figures are simply guides that one might use in figuring the amount of hay necessary under different feeding methods.

Does it pay to feed grain to dairy cattle? This question has been considered by many dairymen. Most of the experiments that have been carried out to solve it have been in the area where alfalfa hay is easily grown and where the quality of alfalfa hay is of the best. The answer depends upon several factors which are stated by the Nevada Experiment Station [1] as follows:

Favoring Grain Feeding	*Opposed to Grain Feeding*
High hay prices	Low hay prices
Low grain prices	High grain prices
High prices for dairy products	Low prices for dairy products
High-producing cows	Low-producing cows
Poor-quality hay	Good-quality hay

"The correct answer to the question 'Does it pay to feed grain to dairy cows?' varies with changes in economic conditions and in the productive capacity of the cows and must always be qualified so as to apply to some given combination of the factors mentioned above." As a rule, however, it would seem advisable to feed at least a limited amount of grain for the most economical results.

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LECTURE XVI

PASTURES

PASTURE is the natural feed for dairy cattle and in many respects the best. Abundance of good pasture will give most of the requirements of a good dairy ration for economical milk production. The amount of land now in pasture in the United States is very great. The total land area of the United States is 1,903,265,000 acres, of which 878,789,000 acres are productive. Of these, it has been estimated that at least 350,000,000 acres are used annually for grazing

FIG. 25.—A pasture scene in Holland (*Anthony*).

purposes.[1] Except in very specialized dairies and a few small sections of the United States, pasture is of the greatest importance in the production of milk. It has been estimated that more than half of all the milk produced in this country is produced on pasture. In many sections the number of cows kept is determined by the number that can be pastured. There is an old Flemish proverb which says, "No grass, no cattle; no cattle, no manure; no manure, no crops."

[1] Range and Pasture Management, Sampson.

This is true to a certain extent in many sections of our country today. Pasture is one of the best feeds for dairy cows from a nutritional and physiological standpoint. Fresh pasture is palatable, is succulent, and has a good physiological effect upon the cow. It is rich in protein, vitamins, and minerals. However, one should realize that pasture is not a concentrate and that heavy milking cows cannot consume enough of pasture for maximum milk production. The pasture should be supplemented with grain if the maximum production is to be secured.

Kinds of Pasture

Pastures are classified according to the nature of the plant which is used as permanent and temporary, although some crops may serve as either temporary or permanent, depending upon the need.

Economy of Permanent Pastures

Permanent pasture is one of the most economical feeds available for dairy cattle. This is due to the fact that it requires very little labor and care, as compared to most other crops. Permanent pastures will last for many years if given proper care, and there is no labor expense in fitting the soil each year or in harvesting since the cows harvest the crop themselves. Furthermore, though pastures must be fertilized at intervals, they do not require so much fertilizer as land in cultivated crops. Pastures also tend to prevent erosion, since the ground is covered the entire year.

Milk and butterfat can be produced by cows on pasture at a much lower feed cost than by barn-fed cows. This is indicated in Table XL, in the three-year average of the monthly production of the cows in the Dairy Herd Improvement Association in West Virginia, which is fairly typical of conditions in the blue-grass section of the United States.

Some of the dairymen started to pasture in the latter part of April and some continued into the latter part of October, although other feeds were fed as needed during the entire summer. It can be seen that the feed cost of 100 pounds of milk and 1 pound of butterfat decreased 50 per cent during the early pasture season and increased during the latter part of the summer when the pasture became short.

TABLE XL

MONTHLY PRODUCTION, FEED COST PER 100 POUNDS MILK PER POUND FAT

(Three-year average, West Virginia Herd Improvement Association)

Month	Number of Cows	Average Milk Production, lb.	Fat Production, lb.	Feed Cost per Cwt. Milk	Feed Cost per Pound Butterfat
January	2115	599	25.3	$1.35	$0.32
February	1961	570	24.5	1.26	0.29
March	1703	694	29.6	1.23	0.29
April	1819	652	27.9	1.10	0.26
May	2227	737	31.2	0.59	0.14
June	1937	676	28.6	0.62	0.14
July	2041	658	28.2	0.63	0.14
August	2128	655	28.2	0.68	0.15
September	2586	582	25.4	0 72	0.16
October	2164	566	26.2	0.88	0.19
November	2350	516	23.2	1.28	0.28
December	2256	560	25.0	1.36	0.31

YIELDS OF PASTURES

There is a prevailing opinion that lands put to permanent pasture will not yield a return in comparison with the value of the land or with the returns secured from other crops. Even though this is undoubtedly true of much of the pasture land in the United States as it is now handled, it need not be so. The farmers in Holland make extensive use of pasture on land which is valued at $500 to $1000 per acre and which annually rents for more than most of the land in this country would bring if sold. This land, however, is not considered as waste land, nor is the pasture a neglected crop. Indeed, the pasture sod, some of which is more than one hundred years old, is more carefully handled than any other crop on the farm. Care is taken that the cattle are not placed on it too early, that it is not over-pastured so that the plants are destroyed, and that the sod is as carefully and as systematically manured and fertilized as for any other crop.

In the United States, a permanent pasture that will furnish abundant feed for a 1000-pound cow for the season, on 2½ acres,

is considered a good one. A comparison of the feeding value of a Kentucky blue-grass pasture and of a dry ration off pasture was made at the Pennsylvania Experiment Station.[1] The feeding value and carrying capacity were estimated in terms of dairy cattle producing different quantities of milk. Eighty pounds of green grass per head each day was taken as the basis of computation. Cows producing 20 pounds of milk daily do not usually require any supplementary feed; cows producing more than this should be given some feed in addition. The dry ration fed while the cows were not pastured was figured according to the Morrison standard.

FIG. 26.—Dairy herd on a good permanent pasture.

Table XLI shows the difference in favor of pasture as compared with dry feeding. This does not represent the acre value of pasture but simply the value of an area capable of producing 12,000 pounds of green grass during a period of 150 days. The investigators found that it required from less than 1 acre to more than 2.5 acres to support a cow for this length of time, depending upon the type of the soil and its treatment. Many of the ranges and unimproved pastures require as many as 10 to 20 acres for each animal. Most pastures of this kind might be easily improved.

[1] Pa. Exp. Sta. Bul. 195.

TABLE XLI

VALUE OF KENTUCKY BLUE-GRASS PASTURE FURNISHING 80 POUNDS OF GREEN GRASS PER DAY FOR A PERIOD OF 150 DAYS

(Cost of feed for 150 days)

	Pasture	Dry Ration off Pasture	Difference in Favor of Pasture
1200-pound cow:			
20 pounds 3.5 per cent milk daily..	......	$44.67	$44.67
35 pounds 3.5 per cent milk daily..	$19.20	56.74	37.54
50 pounds 3.5 per cent milk daily..	33.84	71.12	37.28
Average....................	$17.68	$57.51	$39.83

DISADVANTAGES OF PERMANENT PASTURE

The main disadvantage of a permanent pasture is that during the latter part of the season it often does not produce as much feed as is needed. As the grasses become mature, they are less digestible and less palatable; and the protein, vitamin, and mineral content decrease. During this period it is usually necessary to have some supplementary feed such as temporary pasture, soiling crop, or summer silage. The so-called "dormant period" of blue grass may be due not so much to the nature of the plant as to the lack of moisture. Experiments carried on by the Department of Agriculture [1] at twelve different stations in this country indicate that there is no practical way of producing a uniform growth of grasses throughout the entire growing season. The total yield of dry matter varies greatly not only with the different pastures and localities but also from year to year on the same pasture.

DESIRABLE CHARACTERISTICS OF A PASTURE

A pasture, to be of the greatest benefit to the dairyman, must possess certain characteristics which make it desirable. Some of the points to be considered in judging the value of a pasture are as follows:

[1] U.S.D.A. Tech. Bul. 465.

Density.—A pasture, to be good, should have a dense sod, as this determines the amount of forage available for the cattle. If the sod is not dense, more acreage will be necessary, with the result that the cattle will have to graze over a larger amount of land in order to obtain sufficient feed.

Palatability and Digestibility of the Plant Cover.—The palatability and digestibility of the plant cover determine its nutritive value and the amount of feed that will be eaten by the cattle. The pasture grasses, of course, should be palatable and highly digestible. Certain grasses may change in their palatability and digestibility as the season advances. It is important that a pasture grass remain palatable and nutritious even after growth has ceased.

Even Distribution of Forage.—The time at which different pastures begin to grow in the spring varies considerably. This determines the time at which the forage is available for spring grazing. Different grasses also show different characteristics in regard to their growth during the summer and early fall months. A good pasture should have the ability to furnish sufficient palatable feed for the cattle throughout the normal grazing season.

Convenience.—Dairy animals require a pasture that is not too far distant from the stable, as they should not be compelled to travel any great distance in order to secure food. It is also very desirable that there be water in the pasture, as cows will produce considerably more milk if they have access to water at all times.

A Good Fence.—A pasture that is not well fenced is always a great annoyance to the owner of dairy cattle. One of the most desirable characteristics of a good pasture is that it have a good fence around it.

Permanent Pasture Crops

Permanent pastures consist of perennial plants and can be used under favorable conditions for many years in succession. They have the advantage that they do not have to be plowed every few years, and furthermore they are adapted to conditions under which plowing is not possible. A large part of the pasture land in the United States is permanent, and rightfully so, since there are many acres on hillsides and lowlands which should never be broken up, but

which should return a very profitable income when in pasture and cared for properly.

Kentucky blue grass, Canadian blue grass, red top, and Hungarian brome grass are desirable permanent-pasture grasses; timothy, orchard grass, red clover, and alfalfa are also desirable but less enduring.

The kind of pasture grown has an influence on the amount produced throughout the year. For example, Kentucky blue grass, orchard grass, and red top, under usual conditions, make a much greater part of their growth during the early part of the season; lespedeza and bermuda grass make much of their growth later in the season. A mixture of early and late grasses will make a more uniform seasonal production than either by itself.

Maintaining Permanent Pastures

The cost of maintaining permanent pastures is not great. A survey of the farms in eastern Pennsylvania[1] showed that good blue-grass pasture is about as profitable as any field in the farms. The cost of maintaining it was as follows:

One application of manure once in 8 years at rate of 8 tons per acre	$1.50
One application of lime once in 10 years at rate of 20 bushels per acre	0.55
Repairs and depreciation of fences, per acre	0.65
Taxes, per acre	0.75
Total, per acre	$3.45

These pastures were all in good condition, and some would pasture as many as two cows per acre for the season.

Management of Permanent Pasture

The amount of pasture that can be secured from a given area of permanent pasture depends largely upon the management that it receives. The pasture lands in most sections of the United States have been greatly depleted, and it is necessary that they be built up again if the greatest returns are to be derived from them.

Proper Grazing Methods.—Overgrazing has been given as one of the chief causes of the depletion of pastures. Although this is

[1] Pa. Exp. Sta. Bul. 159.

probably true with certain kinds of pasture, nevertheless undergrazing also has some undesirable results. Experiments at the Virginia Experiment Station [1] show that, with well-established blue-grass pastures, comparatively closely grazed plots gave a higher yield than lightly grazed plots. At the end of three years, it was found that the sod on the closely grazed plots was in a much better condition, with fewer weeds, than the sod in the lightly grazed plots. When pastures are not kept grazed down, many heads form, and the pasture loses in palatability. It should be pastured close enough to keep it from heading.

Cattle should not be turned on pasture until after it has made a good start in the spring, and they should not be pastured too late in the fall. It is never a good practice to turn cows on the pasture in the winter as they secure very little feed and are likely to tramp up the pasture badly.

Alternate vs. Continuous Grazing.—When dairy cows are kept in the same pasture throughout the entire pasture season, it is often difficult to get the pasture grazed uniformly, as the cows consume the pasture near the barn and leave that away from the barn until it has become too ripe. In order to secure more uniform grazing and to give the pasture a chance to grow, a system of dividing the pasture into two or more separate fields and pasturing the animals in succession has been advocated. By this system the cows are turned on the pasture when it is 4 or 5 inches tall and still palatable. As soon as the cows have eaten the pasture down, they are turned in the second pasture. If they cannot keep all the pastures eaten down, one field may be mowed for hay to prevent the bad effects of undergrazing. The increase in the yield of pasture by this method is not great, and it is doubtful if it would pay for the extra cost, as was found at the Washington Experiment Station.[2]

Hohenheim System.—The Hohenheim system, an intensive system of pasture fertilization and management in which alternate grazing plays an important part, has been developed in Germany. The system consists of dividing the pasture into four or five fields, the size depending upon the size of the herd. About 1 to 2 acres are allowed for each 10 cows. Each field is fertilized with phos-

[1] Va. Exp. Sta. Bul. 204.

[2] Wash. Agr. Exp. Sta. Bul. 294.

phorus and potash when needed, and particularly with liberal amounts of nitrogen each year in one or two applications. The cattle are rotated progressively from one field to another at intervals of about a week. The young stock and dry cows are kept separate from the milking herd. They follow in each field as the milking herd advances, eating the remaining and less palatable grasses. In this manner each field is pastured when it is from 4 to 5 inches high, and is eaten completely so that it does not head out. If the cattle cannot eat all the pasture fast enough, one field is mowed when 4 or 5 inches high so that the entire pasture will be kept palatable and not allowed to go to seed and die down. A harrow is run over the pasture at intervals to scatter the droppings.

Such a system, either wholly or in part, has been tried at several experiment stations in this country. The Ohio Experiment Station,[1] after two years' experience, states that the results "appear to indicate the following advantages: (1) a lengthening of the grazing season by about 3 weeks; (2) an increase in protein content of the herbage and in total production of both protein and dry matter; (3) an increased carrying capacity per acre, with corresponding decrease in grazing area required; (4) a reduced manger feed consumption; and (5) an increased density of turf. Disadvantages inherent in the system are: (1) a relatively high acre cost; (2) the need of skillful grazing management; and (3) the difficulty of maintaining white clover in the herbage." This system has not as yet gained wide popularity in the United States.

Pasture Fertilization.—Pastures usually respond remarkably well to fertilization. They cannot be expected to maintain their yield year after year unless some plant food is added to replace that which is removed by the growing crop. If fertilizers of some kind are not added, the yield of pasture gradually decreases until the pasture becomes unprofitable. One should always realize that a pasture should be treated like any other crop, and should not be expected to produce a crop year after year without any fertilizer.

The fertilizer treatment for a pasture varies greatly, depending upon the type of soil and its previous treatment. If the soil is acid, a certain amount of lime must be added before other fertilizer treatments will be of much benefit. On most types of soil, phos-

[1] Ohio Exp. Sta. Bi-Monthly Bul. 152:155.

phorus is the limiting factor, but often potash will have excellent effects. Whether or not these fertilizers will give good results depends largely upon the amount of these elements in the soil, but many experiments have shown that most soils will respond to these fertilizers. This type of fertilization will not only increase the amount and growth of the grasses but will also encourage the growth of white clover and other legumes which are beneficial in adding nitrogen to the soil.

If the acreage is low, so that it is desirable to increase the yield, it is often advisable to add some nitrogen fertilizer. This is usually added at least twice during the season. Nitrogen fertilization results in a much greater yield of grasses, but usually there are fewer legumes. It will bring on the pasture in the spring about two weeks

TABLE XLII

YIELD AND VALUE OF MILK, LESS COST OF CONCENTRATES AND FERTILIZER ON FERTILIZED PASTURE

Acre basis—season of 1934

Fertilizer Treatment	Pounds of 4% Milk Produced	Value of Milk at $2.00 per Cwt.	Cost of Concentrates at $1.50 per Cwt.	Cost of Fertilizer	Returns above Cost of Concentrates and Fertilizer
Lime	755	$15.10	$3.13	....	$11.97
Lime and phosphorus	1576	31.52	5.66	$1.92	23.94
Lime, phosphorus and potassium	1471	29.42	5.67	3.17	20.58
Lime, phosphorus, potassium and nitrogen	1643	32.86	5.87	5.51	21.48
Lime, phosphorus, potassium and nitrogen (put on at 2 times)	1001	21.82	4.49	5.75	11.58
Lime, phosphorus, potassium, 2 nitrogens	2161	43.22	8.83	7.97	26.42
Lime, phosphorus, potassium, 2 nitrogens (put on at 2 times)	1735	34.70	7.12	8.15	19.43
Lime, phosphorus, potassium, 3 nitrogens (put on at 2 times)	2236	44.72	9.34	10.45	24.93

earlier than normal. Such fertilization can often be practiced to advantage when used with heavy milking dairy herds but cannot be relied upon to give yields during the dry season of the year. The question as to whether it is profitable to fertilize pasture has been asked by many dairymen. A study made at the Pennsylvania Experiment Station [1] has attempted to answer this question under the conditions as found in central Pennsylvania. These results may not apply to all conditions but may indicate what might be expected from such treatments. The results are given in Table XLII.

The data indicated that a satisfactory return was made for money expended for fertilizer in all treatments but one. The second application of nitrogen brought little or no return because of extremely dry weather which continued for several weeks.

Cutting the Weeds.—Weeds in a pasture usually indicate depleted soil conditions. If the soil is built up so that pasture does its best, weeds are very seldom found. The weeds, however, should be kept out of pastures since they tend to crowd out the desirable plants and hinder their development. They should be cut at least once every year.

Certain weeds, such as the wild garlic and leek, cause very serious trouble in a pasture. Wild garlic, when eaten by milking cows, taints the milk and makes it unfit for consumption. Garlic will go quickly through the animal's body and enter the milk. Experiments have shown that it can be tasted in the milk within three minutes after it has been eaten and that it can still be detected twelve hours after being eaten. Such weeds should be eliminated from the pasture.

Care should be taken to eliminate plants of poisonous nature from the pasture. Some species of the oak, withered wild cherry, and several other weeds and leaves will kill cattle which eat them.

Temporary Pastures

A temporary pasture lasts for only one or two years and is designed to carry stock only for such a period. On account of the large amount of work necessary to prepare the ground and to sow the seed, this type of pasture has nct been used extensively in the

[1] Pa. Exp. Sta. Bul. 323.

past in many parts of the United States. In some sections, however, temporary pastures are now being widely used. Their advantage is that the yield is very much greater than that of a permanent pasture, and that they may furnish pasture during the so-called "dormant period" of blue-grass and other permanent pastures.

Sweet Clover has been highly recommended for a temporary pasture. It is a biennial and seldom blossoms the first year. It is usually sown with a nurse crop in the spring and is often pastured to some extent the following fall. During the first season one may expect to get very little return from a sweet-clover pasture; but

FIG. 27.—A luxuriant sweet clover pasture.

during the second year the yield will usually be extremely good, especially in the early part of the season. It has the disadvantage that in at least part of the country its greatest yield comes at the time of year when the permanent pasture is at its best, and hence is not a good supplement for these pastures. It has a bitter taste and, until the cows become accustomed to it, some trouble is experienced in getting them to eat it. Bloat is sometimes caused by pasturing cows on sweet clover.

Alfalfa is sometimes used for pasture. It is very palatable and has a large carrying capacity. It should not be pastured the first

year after it is seeded, and not too heavily the second year; but later it can be pastured safely without hurting the stand. However, it should not be pastured too close, especially in the fall. There seems to be more danger from bloat with alfalfa than with other crops, and great care must be taken to prevent losses from such cause. One method which has given good results is to cut the first crop of alfalfa for hay and to pasture the second and third crops. This will give pasture during the season of the year when permanent pasture is least productive. If pasture is needed early, the first crop is pastured and the second cut for hay. It can be used also as a permanent pasture.

Sudan Grass is one of the most popular temporary pastures as it can be planted so as to fit into the time when most needed. It is drought resistant and a warm-weather plant, so it should not be planted until the ground has warmed up well in the spring. It is a non-legume, and is often planted with soy beans, which add to its nutritiveness but not to its total yield. Sudan grass does not cause bloat like sweet clover, but occasionally, especially when the growth has been stopped by drought or by frost, prussic acid poisoning results with the pasturing of sudan grass.

Other crops which are used in various parts of the country for temporary pastures are oats, field peas, millet, and lespedeza. All these have been used successfully. The aftermath of red clover or clover and timothy may also be used for pasture during late summer months.

Comparison of Alfalfa, Sweet Clover, and Sudan Grass.—The South Dakota Station [1] has made a study of alfalfa, sweet clover, and sudan grass as a pasture for dairy cows. Table XLIII shows the amount of milk and butterfat produced per acre per day per season by each of these crops.

Under the conditions found in South Dakota, sudan grass, though a short-season crop, produced more pasture for the time it was used than either alfalfa or sweet clover. It did not, however, furnish as many pasture days.

As a supplementary pasture, it has the advantage over sweet clover of furnishing the pasture when needed. During the season,

[1] S. D. Agr. Exp. Sta. Bul. 265.

TABLE XLIII

MILK AND BUTTERFAT PRODUCED PER ACRE PER DAY PER SEASON BY COWS PASTURED ON ALFALFA, SWEET CLOVER, AND SUDAN GRASS

Year	Alfalfa		Sweet Clover		Sudan Grass	
	Milk, lb.	Butterfat, lb.	Milk, lb.	Butterfat, lb.	Milk, lb.	Butterfat, lb.
1927	40.2	1.48	50.4	1.83	*	*
1928	22.6	0.97	28.3	1.19	46.2	2.00
1929	35.7	1.64	43.7	1.83	39.8	1.82
1930	55.2	2.29	*	*	56.3	2.26
1931	40.9	1.65	58.1	2.22	*	*
Average	38.9	1.61	45.1	1.76	47.4	2.03

* No pasture available.

however, it will not produce as many pasture days as sweet clover. Three years' trial at the West Virginia Station, Table XLIV, shows

TABLE XLIV

PASTURE DAYS AND TIME OF YIELD OF BLUE GRASS, SWEET CLOVER, AND SUDAN GRASS

(Three-year average)

Pasture Crop	Average Pasture Days per Season per Acre	Percentage of Pasture Days before Aug. 1	Percentage of Pasture Days after Aug. 1
Blue grass	138.9	56.3	43.7
Sudan grass with soy beans	95.3	0.7	99.3
First year sweet clover with oats	42.8	49.8	50.2
Second year sweet clover	132.2	100.0	....

that sweet clover furnishes most of its pasture during the early months and sudan grass furnishes it in the latter part of the season.

Feeding Cows on Pasture

As previously noted, pasture is not a concentrate and it is impossible for heavy milking cows to consume sufficient pasture to furnish the necessary nutrients for their milk production. As a result, such cows will decline rapidly in their milk production after the flush of the pasture is off, unless they are given some feed along with their pasture. Even the best pastures will furnish only enough nutrients for cows producing from 20 to 30 pounds of milk per day, so that it is necessary to recognize this fact and to supply the cows with additional feed before they drop too rapidly in their milk production. After cows once decline in milk production, it is difficult to get them back; hence less milk will be produced during the entire lactation. When the permanent pasture begins to decline, it should be supplemented with temporary pasture, silage, soiling crops, or good hay in addition to a grain mixture, in order to maintain the milk production.

The amount of grain mixture to feed will vary with the kind of pasture, the amount of milk that is being produced, and the test of the milk. A guide for feeding cows on pasture is given in Table XLV.

When the pasture is good, less grain is needed than when it is fair. Supplemented with abundance of good hay, silage, or soiling crops, the pasture would be considered good; but if no such supplement is available, pastures will usually be considered only fair, after the flush is off in the spring. Temporary pastures are usually classified as good pastures until they are pretty well eaten down. It is usually unwise to feed grain in amounts above those indicated in the table. Supplementary feeds of other kinds should be supplied if the cows are heavy milkers. The amount of protein in the grain mixture for cows on pasture need not be high when the pasture is good. Young pasture grasses are fairly rich in protein, and often contain considerable legumes. Hence a grain mixture consisting of home-grown grains and containing not more than 12 to 14 per cent protein can be fed with good results. As the late summer approaches, the pasture grasses contain considerably less protein, and at that time the protein content of the grain mixture should be

TABLE XLV

GRAIN FEEDING GUIDE FOR COWS ON PASTURE *

Pounds of Milk Produced Daily	Pounds of Grain Required Daily By			
	A 1200-lb. Cow Testing 3.5% When Pasture is		A 1000-lb. Cow Testing 5% When Pasture is	
	Good	Fair	Good	Fair
10	......	......	......	1.0
15	......	1.5	......	3.5
20	......	3.5	1.5	6.0
25	2	5.5	4.0	8.5
30	4	7.5	6.5	11.0†
35	6	9.5	9.0	13.5
40	8	11.5†	11.5†	16.0
45	10	13.5	14.0	18.5
50	12*	15.5	16.5	
55	14	17.5	19.0	
60	16			
65	18			

* W. Va. Exp. Sta. Circ. 74.
† Never feed a cow more grain than she can safely handle. Cows in heavy production may "go off feed" when fed the amounts of concentrates required to maintain both a high level of production and body weight.

raised to 15 to 17 per cent. It is seldom necessary to go over 18 per cent unless the pasture is very poor.

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LECTURE XVII

SOILING CROPS AND SUMMER SILAGE

THE practice of cutting crops green and feeding them in that condition to dairy cattle has long been followed. It is a common custom in Continental Europe, except in the high Alps. In the valleys of Switzerland all crops are harvested and brought to the cattle. There, only the highest-producing cows are kept in the barn and fed soilage, while the low producers are turned out to pasture on the heights. In our own country, however, the custom of feeding green crops has never become general. It is practiced to a limited extent in certain localities, especially around some of the larger cities. Partial soiling is practiced to a considerable extent, however.

The first comprehensive account of soiling crops written in this country was published in 1820 by Josiah Quincy. It appeared in the *Massachusetts Agriculture Journal* and was later published in a booklet entitled, "Soiling of Cattle." Soiling is especially suitable where intensive agriculture is necessary, as it requires a small amount of land but considerable labor.

ADVANTAGES OF SOILING

Soiling has several distinct advantages as compared with pasturing.

1. A Large Amount of Feed Can Be Obtained per Unit of Land.—There is no question that a much larger yield to the acre can be obtained in the form of soiling crops than in the form of pasture. Detrick [1] was able to produce all the roughage necessary to feed thirty head of stock, seventeen of which were in milk, on 17 acres, by the use of soiling crops. Henry [2] found that it required 3.8 acres of excellent blue grass to pasture three cows for a period of 122 days, whereas he was able to keep three others for the same length of time with soiling crops on 1.5 acres of land. Frandsen, at

[1] Farmers' Bul. 242.

[2] Wisc. Exp. Sta. Rept., 1885.

the Nebraska Station,[1] was able to keep four cows on 1.47 acres of soiling crops during the summer, adding only some field corn and, in one year, alfalfa for thirteen days. These results show that it is possible, by this intensive method, to double or triple the production that could be obtained by pasturage.

2. **Less Waste Is Experienced in Feeding.**—When cattle are fed in the barn it is easier to feed them so that there will be no waste, whereas under the pasture system cattle will tramp over much of the pasture and thereby waste it. Neither will they eat from places where dung or urine has recently been dropped. For

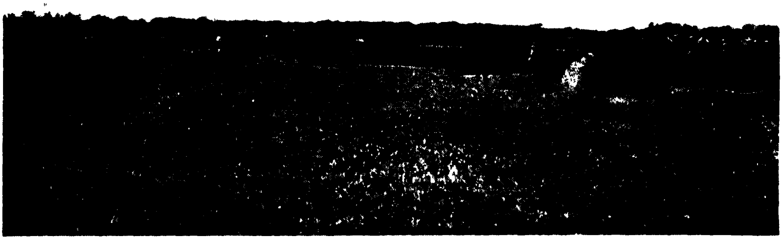

FIG. 28.—Scene in Denmark showing cattle staked out to gather soiling crops.

these reasons there is a valuable saving of feed under the method of soiling crops.

3. **Less Fence Is Required.**—Fences are not necessary where soiling is practiced. This relieves the dairyman of the initial cost of the fence and the cost of its upkeep. If fences are already on the farm very little is saved, but otherwise the saving is considerable.

4. **More Manure Is Saved.**—The manure dropped on the pasture does not do the greatest amount of good unless it is spread. Since cattle do not, as a rule, graze around the droppings, the result is that groups of weeds grow up around them before they become sufficiently decayed for the grass to grow through them. Theoreti-

[1] Jour. Dairy Sci. 4: 124.

cally, the soiling system is a great conserver of manure. About 75 to 80 per cent of the fertilizing value of the crop will be gained under this system if the manure is handled properly.

5. **Animals Keep in Better Condition.**—If the pasture is good at all times, cows will keep in just as good condition when on pasture as when fed a soiling crop. However, pasture usually fails in the late summer, resulting in a lower milk production and a poorer condition of the cows. With a soiling crop this shortage can be avoided and the food supply kept uniform throughout the year.

6. **Undesirable Flavors Can More Easily Be Kept out of the Milk.**—Even good, clean pastures may have weeds that affect the flavor of the milk. These can easily be kept out when soiling crops are fed.

Disadvantages of Soiling Crops

The soiling system also has several distinct disadvantages which prevent its wider use. Two of these disadvantages will be mentioned.

1. **A Large Amount of Labor is Required.**—This is probably the chief reason why soiling has not been more widely adopted in this country. The soiling crops must be cut and hauled regularly whether the weather is good or bad. Since about 100 pounds must be supplied for each cow per day, the labor of handling is considerable. Besides, more labor is required to keep the barns and the cows clean when the animals are kept in the barn than when they are kept on pasture. When land values are high, as they are in Europe and near some of the larger cities in this country, it becomes necessary to use intensive farming systems in order to earn a fair rate of interest on the investment involved. In such cases soiling may be necessary.

2. **It is Difficult to Secure a Proper Rotation of Crops.**—Theoretically, it is easy to establish a rotation which will provide the soiling crops at the proper time. Practically, however, many difficulties occur. Often, because of dry weather, the crops fail or the seeds fail to germinate. At other times cold or wet weather delays certain crops so that there are periods between crops when hay or other feed must be supplied. There is often more or less waste, for the crop is good for only a short time and if not used at once for soiling must be utilized for other purposes.

SOILING CROPS

- Leguminous
  - Annual
    - Canada peas
    - Cow peas
    - Crimson clover
    - Soy beans
    - Vetch
      - Hairy
      - Spring
      - Winter
  - Perennial
    - Alfalfa
    - Alsike clover
    - Red clover
    - Flat pea
- Non-leguminous
  - Annual
    - Corn
      - Sweet
      - Dent
      - Flint
    - Millet
      - Common
      - Hungarian
      - German
    - Oats
    - Rape
    - Rye
    - Sorghum
      - Saccharine
        - Orange
        - Amber
      - Non-saccharine
        - Dhoura
        - Kaffir corn
        - Milo maize
  - Perennial
    - Brome grass
    - Orchard grass
    - Red top
    - Timothy

TABLE XLVI

YIELD PER ACRE OF VARIOUS SOILING CROPS

(Pennsylvania Experiment Station)

Crop	Green Forage, lb.	Air-dry Substance, lb.	Crude Protein, lb.
Canada peas and oats	17,293	2772	326
Cow peas	18,062	3273	503
Cow peas and sorghum	26,375	4512	400
Soy beans	13,019	2689	342
Alfalfa	10,722	2511	419
Dwarf Essex rape	19,370	2714	385
Rye	16,222	3775	353

Crops for Soiling

The classification of soiling crops given on page 227 has been given by the Pennsylvania Experiment Station: [1]

Other crops besides the ones listed above are often grown. The best ones to grow will depend upon the local conditions, as weather and soil vary greatly over the country.

The average yields of a few of the crops are given in Table XLVI. These results were secured at the Pennsylvania Station and are the averages for several years.

The Nebraska Station [2] secured the following average yields of green and air-dry material per acre as is given in Table XLVII.

TABLE XLVII

Yield per Acre of Various Soiling Crops

(Nebraska Experiment Station)

Crop	Green Forage, lb.	Air-dry Substance, lb.
Rye	13,000	1800
Wheat	13,000	1700
Peas and oats	7,000	1800
Rape	12,600	2000
Corn	14,000–16,000	3000–3400
Cane	20,600	5800
Alfalfa:		
1st cutting	10,000	3000
2nd cutting	6,000	1800
3rd cutting	8,000	2400
Pasture	4,500	1000
Silage	16,000	4800

The yields vary considerably even under the same soil conditions.

Amount of Soilage to Feed

There is no reason why the cows should not be fed all they will eat of the soiling crops. The amount which a 1000-pound cow will consume varies from 30 to 100 pounds, depending upon the degree of maturity of the crop and upon the amount of other feed

[1] Pa. Exp. Sta. Bul. 109.

[2] Jour. Dairy Sci. 4: 124.

which is available. When cows are on pasture they will consume from 30 to 50 pounds per day; if no pasture is available they will consume as much as 75 to 100 pounds per day. With certain crops that are very laxative, such as alfalfa, great care must be taken not to feed the cows too heavily at first.

Succession of Crops

The proper succession of soiling crops is very necessary for their success. Most of the systems that have been worked out during

Fig. 29.—Soiling in Sweden.

recent years are centered around alfalfa. The following recommendation for ten cows has been made by the Pennsylvania Station: [1]

TABLE XLVIII

Succession of Soiling Crops in Pennsylvania

Crop	Area for Ten Cows	Time for Feeding
Rye	½ acre	May 15 to June 1
Alfalfa	2 acres	June 1 to June 12
Clover and timothy	¾ acre	June 12 to June 24
Peas and oats	1 acre	June 24 to July 15
Alfalfa (2nd cutting)	2 acres	July 15 to Aug. 11
Sorghum and cow peas (after rye)	½ acre	Aug. 11 to Aug. 28
Cow peas (after peas and oats)	1 acre	Aug. 28 to Aug. 30

[1] Pa. Exp. Sta. Bul. 75.

Table XLIX shows a plan for soiling crops sufficient for ten cows under Nebraska conditions.[1] The rotation may be worked out from the dates. It is centered around alfalfa and corn.

TABLE XLIX

SUCCESSION OF CROPS FOR SOILING CROPS IN NEBRASKA

Crop	Date Sown	Date Harvested	Number of Acres	Yield per Acre, tons	Seed per Acre
Rye or wheat	9/15	5/1 – 5/20	1	5–6	8 pk.
Alfalfa	9/1	5/20– 6/10	½	3–6	18 lb.
Canada peas and oats	4/1	6/10– 6/20	½	9	6 pk. each
	4/10	6/20– 6/30	½	9	6 pk. each
	4/20	6/30– 7/10	½	9	6 pk. each
Alfalfa (2nd cutting)	9/1	7/1 – 7/20	½	1–3	18 lb.
Early corn	5/5	7/10– 7/30	½	10	⅕ bu.
	5/15	7/20– 8/10	½	10	⅕ bu.
Black cow peas	5/15	8/10– 8/20	½	9	4 pk.
Alfalfa (3rd cutting)	9/1	8/20– 9/1	½	2–4	18 lb.
Late corn	5/25	9/1 – 9/20	½	10	⅕ bu.
Barley and peas	8/1	9/20–10/5	½	10	1½ bu.
	8/10	10/5 –10/20	½	10	1½ bu.

These successions are given simply as guides; others may be worked out, or these may be modified to suit local conditions. A suggested succession of crops should be obtained from the nearest experiment station.

PARTIAL SOILING

While complete soiling is practical only where intensive farming methods are necessary, partial soiling is quite largely practiced. During the hot, dry months of summer the pasture usually becomes poor and often scarce, and as a result the milk production will go down. If this happens it is usually very difficult to increase the production after the cows are put into the barn. For this reason the cows should be given some green feed during this time to supplement the pasture. This feed may consist either of some soiling crop or of summer silage.

[1] Jour. Dairy Sci. 4:124.

Sometimes it is necessary to supplement limited pasture with soiling crops. The Iowa Experiment Station used this system with a herd of 40 to 50 cows for which only 20 acres of pasture were available. During eight seasons each cow consumed an average of 1.92 tons of soiling, to grow which required 0.76 acre per cow. If these cows had been on pasture alone, 2 or 3 acres per cow would have been required. The Station experimenters recommend the plan shown in Table L for a herd of 15 cows on a partial soiling system when 10 acres of pasture are also available.

TABLE L

PARTIAL SOILING CROP PLAN WITH ALFALFA

Crop	Area, acres	Approximate Date of Seeding	Approximate Date of Harvesting
Alfalfa (1st cutting)	½	Previous year	June 10–20
Oats and Canada field peas	1	April 5	June 15–July 5
Oats and Canada field peas	½	April 20	June 30–July 10
Alfalfa (2nd cutting)	½	Previous year	July 5–15
Oats and Canada field peas	½	May 5	July 10–25
Amber cane	1	Previous year	July 20–Aug. 20
Alfalfa (3rd cutting)	1	Previous year	Aug. 20–Sept. 1
Corn	1	May 10	Sept. 1–20
Corn	1	May 20	Sept. 15–Oct. 15

COMPARISON OF SOILING CROP AND SUMMER SILAGE

If the number of animals to be fed is sufficient to require that at least 2 inches be taken off the silo per day during the summer, summer silage can be used advantageously. Often a special silo with a small diameter is built for this purpose. It has been found that the use of silage is a cheaper and better way of providing green material during the summer months than soiling. At the Wisconsin Experiment Station,[1] for an average of three years, a group of cows fed silage produced practically the same amount of milk as a group fed soilage, but the expense was considerably greater for the soiling crops. The investigators found that one advantage of

[1] Wisc. Exp. Sta. Bul. 235.

silage is that years of poor rainfall and poor pasture are years of poor soiling crops, while the carrying over of corn in the silo from one year to the next tends to equalize this.

Table LI, from the Nebraska Experiment Station,[1] gives a summary of two years' comparison of soiling and summer silage at that station:

TABLE LI

SUMMARY FOR TWO YEARS—SOILING VS. SUMMER SILAGE

	Average Soiling	Average Silage
Number of days	141	141
Pounds of soilage consumed	61,186.5	
Pounds of silage consumed	....	16,231
Pounds of alfalfa consumed	....	3,933
Pounds of grain consumed	5,408	4,263.8
Pounds of milk produced	13,480.75	11,120.95
Average per cent fat	4.29	4.18
Pounds of butterfat	562.88	465.22
Hours of man and horse labor	247.57	189.32
Grain required per 100 lb. of milk	41.81	40.30
Pounds of soilage required per 100 lb. of milk	470.5	
Pounds of silage required per 100 lb. of milk	....	155.73
Pounds of hay required per 100 lb. of milk	....	36.74
Hours of labor required per 100 lb. of milk	1.813	1.245
Pounds of dry matter required per 100 lb. of milk	149.975	110.555
Pounds of crude protein required per 100 lb. of milk	14.567	10.742
Weight of cows at the beginning	901.2	1,050
Weight of cows at the end	990.5	1,016.5
Acres of ground required	2.445	1.665

The advantages of the summer silo were found to be as follows:

1. The feed was always at hand without any additional work.
2. The silage will keep for an indefinite length of time if properly prepared.
3. The silage was relished just as well as the soiling crops.
4. The silage was independent of climatic conditions as the supply was from the previous summer.
5. The silage was always under cover; there was no harvesting during wet weather.

[1] Jour. Dairy Sci. 5: 124.

6. The silage was a cheaper succulent feed than was the soiling crop.

However, on farms where the number of cows is so small that the silage is not fed fast enough to keep it from spoiling, or where for any reason silage is not available, some soilage crops or temporary pasture should be grown to feed during the hot, dry months of summer and early fall. A good practice is to keep the cows in a cool barn during the daytime and feed them some green feed, and then turn them out to the pasture during the night for grazing and exercise.

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LECTURE XVIII

SOME DETAILS IN DAIRY CATTLE MANAGEMENT

In the management of dairy animals, as in other lines of dairy industry, attention to details is important, but by details it should be understood that necessary details are meant. It is possible for a herdsman to attend to unessential details at the expense of larger and more important matters.

Handling the Herd

Regularity of Care.—The dairy cow, as has been stated before, is a creature of habit. The same system of care should be used each day. It is desirable that the cow have approximately the same amount of exercise, and that she be fed and milked at the same hour daily. This is especially true of animals that are being forced for high production. A change of milkers or even a strange feeder or attendant in the barn has an effect upon some of the more sensitive animals. Most cows can, however, become accustomed to a certain amount of change.

Kindness in Handling.—To keep up the production of a cow one must always treat her with kindness. The beating of a cow should never be tolerated under any circumstances. It is not only cruel but it cuts down the production of milk. A man that cannot control his temper will never make a good dairyman. Dairy cows should never be raced in going to or from pasture or while in pasture. Very few dogs have a place on the dairy farm as most of them will race the cows. The presence of dogs around the farm at milking time, if the cows are not used to them, may disturb the herd to such an extent as to affect not only the quantity of the milk but also its composition.

Exercise.—It is not known just how much exercise is best for a dairy cow. Some herdsmen believe that since the cow's work is to produce milk she can get along without any exercise, provided

that she is kept in a sanitary, well-lighted and ventilated barn. Some herds that are producing well are kept in the barn throughout the year. In general, however, it seems desirable to give the animals at least some exercise as they seem to be a little more thrifty and maintain a better appetite when they are allowed to exercise. This is especially true when they are kept in stanchions, as they are able, when turned out, to rub certain parts of their bodies that they cannot rub when in the stanchion. A common method is to turn them out for an hour or two, even in winter, while the barn is being cleaned. This enables the dairyman to do the cleaning to better advantage and at the same time gives the animals a certain amount of exercise regularly every day. It is possible for a dairy cow to have so much exercise that she will lose energy unnecessarily. This is the case when she has to be driven too far to pasture or when the pasture is so poor that she has to cover too much ground in order to get enough food. Heavy milkers should not be given much exercise. In cold, wet weather the exercise should take place in a protected yard if possible.

Grooming Dairy Cows.—Dairy cows should be groomed every day, especially in the winter when they are in the stable all the time. In summer, when they are on pasture, this is not so necessary. Grooming is essential not only from the standpoint of looks, but also from that of production of clean milk and the health of the animal. By grooming, the dirt and loose hair are removed and thereby prevented from getting into the milk. Grooming, properly done, also stimulates the skin, making it more pliable. It is said to have an effect upon the milk flow of heavy producers which are kept in the stable most of the time.

The method should be, first, to rub the cow vigorously with a brush and curry comb or card, and then to clean her off with either a cloth or a brush. The currying should be vigorous, but not so severe as to irritate the skin. The bone points should be rubbed more gently, especially with the comb.

Dehorning.—Cows in commercial herds that are not kept for show purposes should be dehorned. Cows with horns endanger their attendants as well as one another, and the horns are also an inconvenience in feeding and watering. Cows that are dehorned can be kept together in close quarters or yards without danger. Polled

strains of the various breeds have been developed in order to bring about a hornless condition without the operation of dehorning.

FIG. 30.—The hair is clipped close before the caustic is applied.

Two methods of dehorning are common.

1. *Removing with a Caustic.* — This method is to remove the button-like rudiments of horns in the calf before it is ten days old. For this purpose a stick of caustic potash (potassium hydroxide) is used. The hair around these "buttons" should be clipped close and the caustic potash should be slightly moistened and then rubbed over the "button," or little horn, until the blood appears. This should be carefully done, as otherwise some of the horn cells may not be destroyed and a scur

FIG. 31.—Applying the caustic to the "buttons" of the young calf.

may develop. The caustic should be wrapped in a cloth or paper to protect the operator's hand. In about a week or ten days, the scab that is formed should drop off.

2. *Removing with Forceps or Saw.*—This second method is to remove the horns, after they are partly or fully grown, with forceps or a saw. The operation should take place when the animal is two years of age or older. If it is done at an earlier age, scurs are likely to develop. The best time to dehorn is in the fall or in the spring. It should not be done during fly time. Whichever instrument is used, the practice should be to remove the horn just as near the head as possible. When the ring of hair at the base of the horn is removed in the operation it is seldom that even a small scur will grow. If there is considerable bleeding or if it is necessary to dehorn during fly time, it is advisable to cover the wound with pine tar, or cotton soaked in pine tar, and to bind it up.

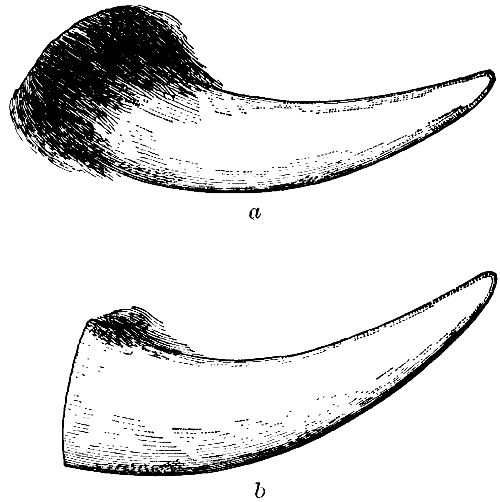

FIG. 32.—The horns should be cut close to the head as shown by *a*.

Spaying.—A theory was prevalent a few years ago that by spaying (removing the ovaries of) dairy cows they could be maintained in milk over a number of years without the interruption incident to calving. This theory was found not to work out, however. Cows would continue to milk for a longer time, but at much diminished milk flow, even though they were spayed immediately after calving. The hormone secretion which circulates in the blood, and which is quite active after parturition, becomes less active after a reasonable number of months, and finally dies out. It must be renewed by the cow's dropping another calf. Moreover, the cow cannot assimilate enough minerals for continued high production.

For these reasons, therefore, spaying was not successful in keeping up a continuous high milk flow.

Watering.—A large amount of water is contained in milk. Dairy cows, therefore, must consume large quantities of water for the production of milk. The amount that a cow will drink depends largely upon the outdoor temperature, the kind of food eaten, and the amount of milk the cow is producing. A large cow producing a heavy flow of milk will easily drink as much as 100 pounds of water per day. If the weather is warm more water is required than in moderate or cold weather. Also, if the feed is of a succulent nature, the cow will consume less water than if she were eating dry feed. In experiments at the Beltsville Station [1] average-producing cows were watered once a day, twice a day, and at will from watering cups. The cows watered once a day drank less and produced less than those watered twice a day, and the cows watered twice a day drank as much but produced less than those watered at will. The difference in production, however, was only about 4 per cent between those watered once a day and those watered at will. It was found that the higher the production the greater the benefit derived from frequent watering.

In an experiment [2] at the Iowa Experiment Station, dairy cows watered by means of water bowls in the barn consumed approximately 18 per cent more water and yielded 3.5 per cent more milk and 10.7 per cent more butterfat than cows watered twice per day at an outside tank. Cows in the barn drank an average of 10 times per day, consuming about two-thirds of their water in the daytime and the other third at night (5 P.M. to 5 A.M.). The cows watered outside twice per day drank only once per day about 30 per cent of the time. The amount of water consumed was about 3.0 to 3.5 pounds for each pound of milk produced.

The temperature of the water should be uniform from day to day. In very cold weather the cows will drink more water if it is slightly warmed. However, except for very heavy producers, this will seldom pay. Ordinarily, if the water is given in the barn there will be no advantage in warming it.

[1] Farmers' Bul. 170.

[2] Iowa Bul. 292.

Marking.—It is necessary to have some way of designating the animals in the herd. Many dairymen name their cows. This is all right in grade herds when the herd is so small that one can keep in mind all the animals. In large herds and in pure-bred herds it is never safe to trust to one's memory. Some method of marking must be used. Five ways of marking cattle are in common use:

1. *By a System of Cuts in the Ear.*—This system is used extensively in numbering pigs, but with dairy cows it is not recommended because of the unsightly appearance and because it would be difficult to read.

2. *By Inserting Special Tags of Various Kinds in the Ear.*—This is one of the best methods although it has the disadvantage

FIG. 33.—Ear tatooed with special marks.

that the tags are sometimes lost. The tags are of many designs. One is provided with a button on each side of the ear, the two being clamped or screwed together. Another consists of a round leather or composite tag which is attached to the ear by a ring similar to a common hog ring.

3. *By Tattooing the Ear or Other Part of the Body.*—This method is used extensively. The method is to punch certain small holes in the form of numbers or letters through the ear and then to fill them with ink. This method is often used as a permanent mark along with some other mark easier to read.

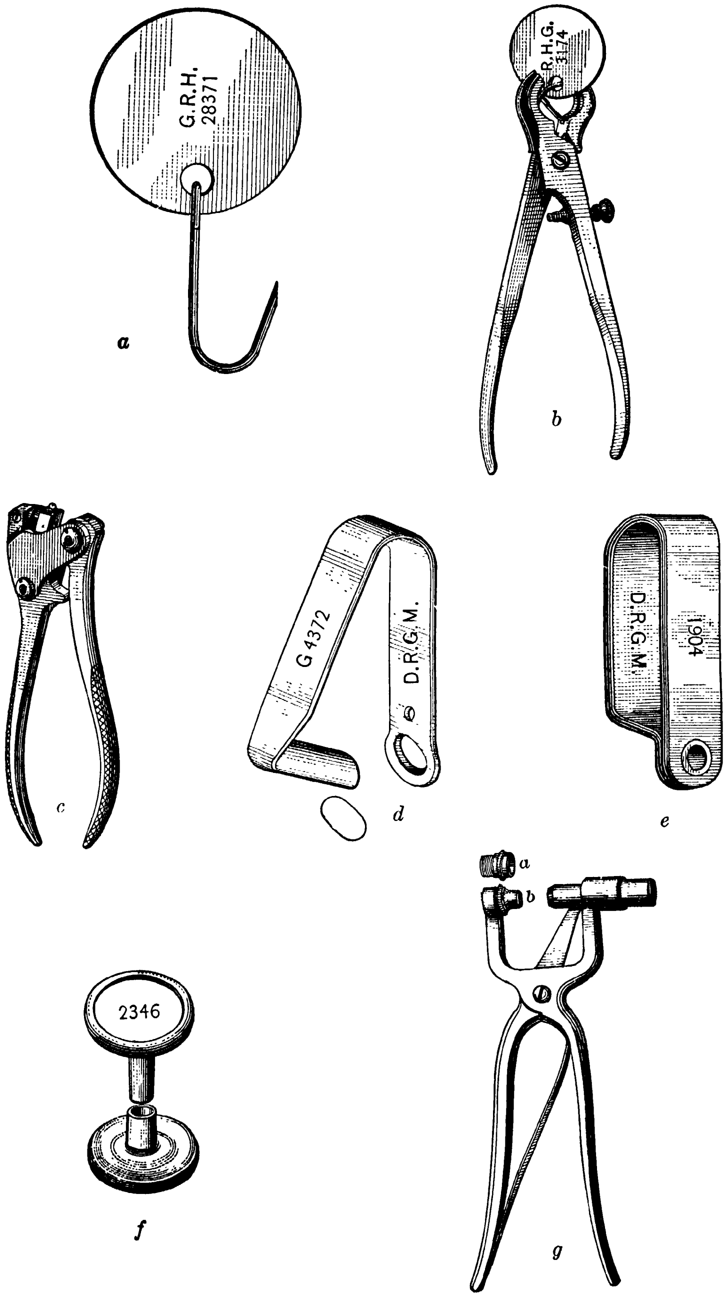

FIG. 34.—Types of ear-markers (*Marquart*).

4. *By Stamping the Number on the Hoof or Horn.*—Although this is a safe way it is not common. Figures or numbers are burnt upon the hoof or horn with dies. This method can also be used for a permanent number.

5. *By the Use of Tags Attached to Straps or Chains Placed around the Horns or Neck.*—The strap is often used on young calves until they are old enough for a permanent mark. In herds where animals are bought frequently and the same number is used over and over, this system of marking is common. By the use of a padlock it becomes more permanent.

Kicking Cows.—There are two classes of kicking cows. One develops the habit of kicking through improper treatment, and the other is characteristically vicious. Of the latter class there are fortunately very few. Practically always, if the animals are carefully handled, especially during the first days of milking while they are heifers, and the teats and udder are carefully protected from soreness or injuries, kindness and patience will transform a kicking cow into a gentle one that can be milked without difficulty. With the vicious cow, however, or with one that has developed the habit of kicking to such a degree that it does not yield to kind treatment, some mechanical device must be used if the cow is worth it. One method is to tie her head high, thus making kicking more difficult. Another is to tie a rope or strap around the body of the cow just in front of the udder; with a good many cows, if this has been used several times, it seems necessary only to throw the strap over the back. Still another method is to loop a rope around the cow's leg above the hock, and to fasten it to some object in the rear so that it will be impossible for her to throw her leg forward. A device which has been somewhat successful is a wooden clamp with one claw in front and above the hock, and one behind and below the hock near the ankle; when the strap is tightened in the center the animal is unable to flex the hock. Perhaps the most common way is to make a simple loop with a strap or rope above the hocks, binding the legs together.

Sucking Cows.—Some cows develop the habit of milking themselves or other cows. There are many patent devices that are effective for overcoming this habit, such as muzzles with sharp nails in them. Most of these require some attention. If they are used on cows that milk other cows there is danger of injury to the udder. A

simple method that works satisfactorily is to insert through the nose of the sucking cow a ring with two or three other rings attached to it. This device needs no attention and does not interfere with the animal's eating, but it interferes with her attempts to suck.

Flies

Flies are a great annoyance around the dairy barn. It seems almost impossible to get rid of them. They can be kept out of the dairy houses by means of screens, but it is practically useless to screen the dairy stable as the flies come in on the cows and the screens often serve to keep them in rather than to keep them out.

Dairymen should, as far as possible, destroy the breeding places of flies. They should keep the manure well cleaned out and all other breeding places cleaned up, and then by the use of sprays and traps reduce the flies to the lowest possible number.

Many different devices have been tried in order to get rid of flies. Some dairymen use poisonous solutions, mixed with syrup, which are put in different parts of the barn in shallow pans; others use fly traps of various kinds. The most common method is to spray the cows with some material which will either kill the flies or else repel them. Many commercial sprays on the market give fairly good results as repellants, but many of them have a detrimental effect upon the cow.

Effect of Flies upon Milk Production.—Flies do not seem to have a great effect upon the milk flow of dairy cows. It was formerly believed that one of the main reasons for the decreased milk flow in the late summer was torment of the flies. The explanation of this is that the appearance of flies in great numbers is coincident with the drying up of the pastures and the beginning of summer heat, so that the dairymen attribute to the flies what is really caused by hot weather and insufficient feed. The effect of flies, as found at the California Experiment Station,[1] is shown in Table LII. The cows were kept in a screened box stall and the flies were liberated in the stalls in very much greater numbers than are ordinarily found in the barn. The decrease in milk flow with the horn flies and house flies was almost negligible, and with stable flies less than 10 per

[1] Jour. Dairy Sci. 19:11.

TABLE LII

LOSSES IN MILK PRODUCTION RESULTING FROM HEAVY INFESTATIONS OF FLIES

Treatment	Average Monthly Milk Production		Losses Attributable to Flies	
	Expected Pounds	Actual Pounds	Pounds	Per Cent
No flies	....	954	..	..
73,000 horn flies	677	667	10	1.4
71,000 stable flies	1055	957	98	9.3
140,000 house flies	890	860	30	3.3

cent. Nevertheless, flies are unsanitary, are likely to contaminate the milk, and are at times very annoying both to the cow and the milker, and therefore every precaution should be taken to keep the number down to the minimum.

Effect of Fly Sprays on Milk Production.—Most commercial sprays, when sprayed on the cows, have been found to have a detrimental effect upon the milk production. At the California Station [1] the effect of sprays on milk production was studied; the results are given in Table LIII.

TABLE LIII

LOSSES IN PRODUCTION RESULTING FROM THE USE OF PETROLEUM SPRAYS DURING HEAVY INFESTATION OF FLIES

Treatment	Average Monthly Milk Production		Loss in Milk Production	
	Expected Pounds	Actual Pounds	Pounds	Per Cent
Yellow oil—no flies	942	900	42	4.3
Yellow oil—23,250 stable flies	986	862	124	12.4
White oil—26,900 stable flies	887	692	185	21.0
White oil—19,600 horn flies	654	566	98	13.1

[1] Jour. Dairy Sci. 19:11.

The loss in milk production due to spraying was in every case considerably more than that due to the flies alone. Apparently the spray had a physiological effect upon the cows, increasing their body temperature and rate of respiration. This was caused by the impairment of the skin so that it did not have the ability to aid in maintaining body temperature. The effect was much more noticeable on heavy milking cows than on those giving little or no milk.

Whitewash

Whitewash is excellent to use in all dairy buildings. It is simple to make and easy to apply, is a mild antiseptic, and is perfectly safe. The following formula has been recommended by the United States Department of Agriculture:

"Take a half bushel of unslaked lime, slake it with boiling water, cover during the process to keep in steam. Strain the liquid through a fine sieve or strainer, and add to it a peck of salt previously dissolved in warm water, 3 pounds of ground rice boiled to a thin paste and stirred in while hot, ½ pound of Spanish whiting, and 1 pound of clean glue previously dissolved by soaking in cold water, and then hang over a slow fire in a small pot hung in a larger one filled with water. Add 5 gallons of hot water to the mixture; stir well; let it stand a few days covered from dirt. It should be applied hot, for which purpose it can be kept in a kettle or a portable furnace. Coloring matter may be added as desired. When a less durable whitewash will answer, the above may be modified by leaving out the whiting and glue and omitting the boiling. It need not be applied hot and may be applied with a spray pump."

Bedding

Some sort of bedding is necessary to provide comfort for the animals, to keep them clean, and to absorb the liquid manure. The amount of bedding required depends upon the kind of floor that is in the barn, and the method of keeping the cows fastened. With a cork-brick or wooden floor less bedding is needed than if other materials are used. Less bedding is also needed if the cows are fastened in stanchions with stalls of proper length than if they are fastened with chains or left loose in a box stall.

The common materials used for bedding are straws of various kinds, corn stover, shavings, and sawdust. The best kind depends upon local conditions. On most farms sufficient straw is available, so that the problem of the proper kind of bedding is easily solved. In many cases corn stover can be shredded and used for bedding. It makes very satisfactory bedding materials.

If the bedding has to be purchased, the relative prices of the various bedding materials will usually be the deciding factor. Shavings have been used extensively in many dairies with good success. They have the advantage that they are clean and give the stable an appearance of cleanliness, which no other material can do. Shavings can be purchased in carload lots, in bales which are easily stored and handled. In regard to cost, the West Virginia Station found that they were the cheapest and most satisfactory bedding that could be obtained. Soft-wood shavings have a very much greater water-holding capacity than those containing some of the hard woods, and are greatly to be preferred.

The absorptive properties of different bedding materials are given by Doane [1] as follows:

TABLE LIV

ABSORPTIVE PROPERTIES OF BEDDING MATERIAL

Material	Water-absorbing Power of Bedding	Pounds of Bedding Required to Absorb for 24 Hours
Cut stover	2.5	4.0
Cut wheat straw	2.0	5.0
Uncut wheat straw	2.0	5.0
Sawdust	0.8	12.5
Shavings	2.0	4.4

The fertilization value of the straws and corn stover is much greater than that of either shavings or sawdust. About 4 to 8 pounds of bedding is required to keep the cow clean when fastened in stanchions with stalls of the proper length.

[1] Md. Exp. Sta. Bul. 104.

Manure Disposal

All manure should be removed from the stable at least once per day, and preferably twice. This can be done by means of a wheelbarrow, or in the larger dairies by means of a litter carrier which runs on a track back of the cows. From this the manure can be dumped directly into a manure spreader and spread at once on the field, or it can be run into a manure pit situated some distance from the barn, where it will remain until it is convenient to spread upon the land. The manure, especially during warm weather, should not be allowed to collect for any great length of time, for it is an excellent breeding place for flies. The practice of dumping the manure in a pile where the rain will wash out much of the fertilizing constituents should never be allowed. Properly preserved manure will return to the soil about 75 per cent of the fertilizing value of the feed, but manure exposed to the weather loses a very large percentage of its value.

Milking the Herd

Next to feeding, perhaps no other operation in the dairy requires so much skill as does milking. Considerable practice is required to become a good milker. A person with soft hands seems to be able to milk more efficiently than one whose hands are hardened with heavy work.

The operation of milking should be uniform, rapid, and continuous until practically all the milk has been drawn. One should not cease milking after one has begun, until the cow has been completely milked. In milking the hands should be dry; the practice of wetting them before beginning the operation is very unsanitary. If it seems necessary to have the hands moist, vaseline may be used without injury to the quality of the milk.

The method of milking should imitate that of the calf as closely as possible. The operation consists of an upward movement followed by a downward pull accompanied by pressure. The whole hand should be used, not merely one or two fingers. Unless the teats are small, the squeezing should be accomplished by closing the whole hand, first at the top of the teat as a check against the backflow of the milk, and then on the rest of the teat.

FIG. 35.—Manure emptied directly into the manure spreader.

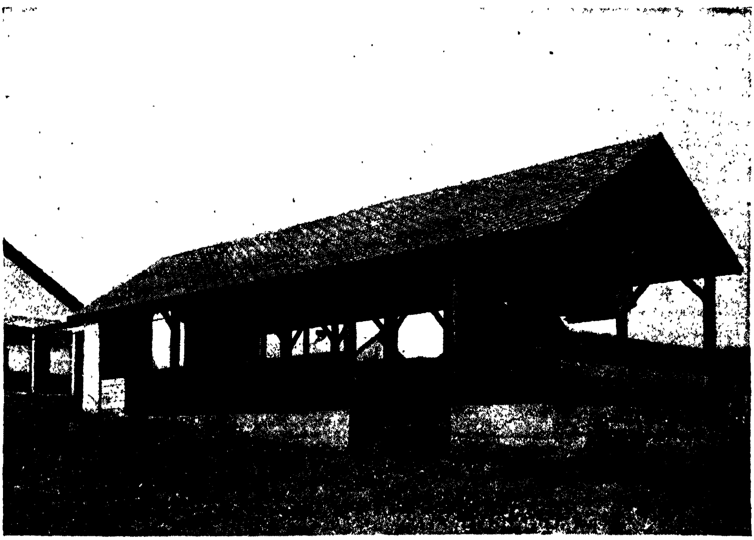

FIG. 36.—A combined bedding and manure storage.

It is customary to milk diagonally placed teats simultaneously, for the reason that there is a blood connection between the teats on the same side, but not between those on opposite sides. It is believed that by milking alternate teats both sides of the udder are stimulated at the same time, and that changing to the other alternate pair permits secretion to proceed in the first two.

There is considerable difference in the length of time required to milk different cows, but on the average a good milker can milk six to ten cows per hour, the number depending somewhat upon the ease with which the cows can be milked. There is little difference, however, in the time required to milk cows that give large amounts of milk and those that give small amounts. When the milker is expected to weigh and sample the milk, a smaller number of cows can be milked per hour.

Milking with a Milking Machine.—The milking machine is a success on many diary farms. It has the advantage that it saves labor and time and is easier on the milker. The initial cost and the labor of keeping the machines in proper sanitary condition are disadvantages, especially when the herd is small.

As far as quantity of milk is concerned, the milking machine seems to give just as good results as ordinary hand milking. It is the general practice for the hand milker to follow the machine in order to see that the milking has been done completely and to draw any milk that is left.

It has been claimed that the milking machine causes udder troubles. This was undoubtedly true with some of the older types of machines, especially when they were left on too long; but the newer machines are so constructed that when properly handled there is now little danger of such trouble.

The difficulty of keeping milking machines clean is the greatest drawback experienced with their use. Theoretically, milk drawn with a machine should be cleaner than that drawn by hand as it is better protected from the surroundings, but often milk produced in this way contains more bacteria than that drawn in the ordinary way. However, when the machines are given proper care, the bacteria count of the milk is kept quite low. Failure of the milking machine is usually due to lack of mechanical knowledge on the part of the operator, to his carelessness, or to his lack of attention to proper cleaning of the machine.

Some dairymen feel that the use of the milking machine results in a decrease in the milk production. An experiment to determine this point was carried on at the New York Experiment Station [1] in which the cows at 2, 3, and 5 years of age were milked for complete lactations by machines and at 4 years of age by hand. Slightly more milk was given by the cows milked by hand, but this increase in production was evident only after the third month of lactation. In other words, the hand-milked cows were more persistent in maintaining milk production than the machine-milked cows. They believe that this difference may have been due to incorrect methods of handling the machine rather than to the machine itself. However, an experiment carried on at the Danish Research Laboratory [2] indicated that good hand milking gives a little more milk than machine milking.

Stripping the Cows.—The hand stripping of cows after the milking machines has been one of the most serious objections to the use of milking machines. This is especially true with the "combine" milker, since the milk is handled entirely by machinery and stripping slows down the process and makes it impossible to put it all through the machine. In order to avoid stripping, some dairymen have discontinued hand stripping, while others have massaged the udder while the machine was still in operation in order to remove all the milk. It has been the general belief among dairymen that if the cows were not milked completely dry it would (1) tend to cause them to drop off rapidly in their milk flow, (2) cause udder trouble, and (3) increase the bacteria content of the milk.

In order to determine the effect and practicability of this method, various experiments [3] have been run. Cows have been milked for a complete lactation by hand and another lactation by machine, and the results compared. It was found that leaving a pound or two of milk in the udder at each milking did not affect the percentage of fat in the milk, the normality of the milk either in regard to composition or bacteria count, the persistency of the cow, or the health of the cow. The amount of milk produced when the cows were not stripped was 96.7 per cent of the production when they were milked completely. An average of 1.2 pounds of milk and 0.09

[1] N. Y. Exp. Sta. Bul. 654.
[2] Hansen's Dairy Bul. 20: 25.
[3] U.S.D.A. Tech. Bul. 522; Jour. Dairy Sci. 17: 331.

pound of butterfat was left in the udder when the cows were not stripped. In order to get this milk by stripping, it required 1.57 minutes per cow per day, so that each hour of labor spent in stripping resulted in 1.16 pounds of butterfat. Under ordinary farm conditions, it would therefore usually be profitable to strip the cows, but if labor was high or if the use of the combine made stripping inconvenient, no special harm will result from not stripping.

Although these experiments were conducted with the milking machine, the results would indicate that even with hand milking it might not be profitable to try to get the last drop of milk from the cow, as the cost of the stripping might be more than the value of the milk. Nevertheless, it would seem advisable not to leave very much milk in the udder.

Frequency of Milking.—The frequency of milking should depend upon the ability of the cows to produce milk. The effect of milking cows more than twice daily may be to increase the milk production, increase the percentage of fat in the milk, influence the persistency of lactation, and influence the amount of udder trouble in cows. In general, a cow that produces 50 or more pounds a day should be milked more than twice daily. With cows giving less than this amount it is probably not profitable, from the standpoint of actual amount of increase in milk flow, to milk more than twice. Experiments have shown that more milk and fat are produced by milking three times than by milking twice. At the United States Dairy Division farm at Beltsville it was estimated that the average increase in the yield of good cows for short periods (40 days) due to milking them three times instead of two was about 12 per cent, and for longer periods (a year) the increase was about 18 per cent. The cows milked three times a day were more persistent than those milked only twice. It was also estimated that the increase due to milking four times a day was 6 to 7 per cent over milking three times a day. With high-producing cows at the Nebraska Station [1] the yields were even greater. Cows of the four main dairy breeds, milked three times per day, produced from 40 to 52 per cent more fat and from 45 to 65 per cent more milk than cows milked twice

[1] Nebr. Exp. Sta. Res. Bul. 59.

daily; and when milked four times per day they produced from 110 to 128 per cent more fat and from 149 to 160 per cent more milk than those milked twice daily. There was a slight tendency for the fat percentage to be higher with the additional milkings and the persistency of the cows was increased. Whether or not it will pay to milk more than twice depends upon individual conditions. In large herds where the system of labor can be handled, it may be advantageous to milk three times a day, even in a regular commercial herd. For very high-producing cows, or cows that are being forced for high records, it is customary to milk four times a day.

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LECTURE XIX

RAISING THE DAIRY CALF

THE total number of dairy cows in the United States in 1937 was approximately 25,000,000. The average age at which the cow in the United States is removed from the herd has been found to be seven and three-fifths years. Assuming that a cow gives birth to her first calf at two and one-half years of age, and to one calf each year thereafter, this means that the average cow can give birth to five calves in her lifetime. Her period of usefulness in the herd, therefore, is just a little over five years. At this rate more than 5,000,000 calves must be raised every year in order to maintain the present number of dairy cows. Furthermore, it is necessary to raise approximately 350,000 more calves to keep up with the increase in population. Many calves die while being fed milk, and a large number are disposed of later, so that most dairymen must retain at least three calves for each two cows that are to be replaced in the herd. Therefore, the number of calves actually being raised in the United States at any time is very large.

IMPORTANCE OF RAISING DAIRY CALVES

It is now a well-known fact that the dairy cow inherits her milk-producing ability, and that it is impossible by any kind of feeding to make an animal produce milk in excess of her inheritance. Since this is true, it is very essential that the dairy farmer raise only the heifer calves of cows possessing high milk-producing qualities. This is the way in which he can hope to maintain the production of his herd at its present level. By careful mating and feeding he may even develop a herd of cows with a higher average production than that with which he started.

Near the larger cities where the price of milk is high, many of the dairymen, instead of raising calves, depend upon purchasing cows with which to maintain their herds. While from the stand-

point of immediate monetary return this method may be the best, nevertheless it has several disadvantages which make it very undesirable. In the first place, only too often the cows that can be purchased are culls which the owner himself does not want, and if the best cows in a herd are purchased the price which is paid is usually very high. Furthermore, the buyer always runs the very great risk of bringing diseases, such as tuberculosis and abortion, into his herd. It is a well-established fact that little or no improvement results where this method of maintaining the herd is followed. Herd improvement can come only where discarded cows are replaced by well-raised heifers of good breeding and type. The only

FIG. 37.—The future herd (*Buckley*).

sure and practical way in which the dairyman can secure these is to raise his own heifer calves from the best cows in the herd and with the use of a good pure-bred bull. There are successful specialized dairies in which no young stock is raised, but such herds show no improvement from one year to the next, while the dairyman who raises his own replacements with careful breeding and attention to details may hope to improve his herd from year to year.

CARE OF THE COW AND CALF AT CALVING TIME

If the cow is confined in the barn she should be put into a well-bedded box stall a few days previous to the time of calving. Although it is not always necessary for the attendant to be present

while the cow is calving, he should be near by, where he can give assistance if necessary; but he should disturb her as little as possible. If the cow calves normally she will immediately begin to lick the new-born calf, and will thus start respiration, improve the circulation, and dry the young animal. It is important that the mother begin to lick the calf soon after it is dropped. Sometimes the fetal membrane covers the nostrils, and the young calf will suffocate unless this is promptly removed. Occasionally a young mother, even though she may have had several calves, will refuse to own her offspring. In such cases it is necessary to remove the calf to a safe distance and to dry it with burlap or other dry cloths. Generally, after a brief absence, the calf may be returned, and the mother induced to adopt it.

A vigorous calf will attempt to rise in about fifteen minutes and usually will be nursing in half an hour. The weaker the calf, the longer the time before it will be able to be up and nursing. Some calves are unable to nurse by their own efforts; then it is necessary to assist the calf by holding it up to the cow's udder. If the calf is so weak that it is unable to drink, even when held up, it may be necessary to feed it from a bottle, either by drenching or by fitting the bottle with a nipple. It is always desirable to treat the navel with a strong solution of creolin or other disinfectant, after which it should be washed with tincture of iodine. This may prevent disease germs from entering by this means.

Care of the New-born Calf

The first milk that a cow gives after dropping a calf is called "colostrum." It differs from normal milk in that it is thick and yellow and contains much more protein and ash. This abnormal milk is given for several days, gradually changing to normal milk. It is usually considered fit for human consumption after the eighth milking following the cow's freshening.

It is very important that the calf receive the colostrum. It seems to be the special purpose of this milk to cleanse away the metabolic products that have collected in the intestines of the young animal during the latter portion of its fetal days. Experiments [1] have shown

[1] Jour. Exp. Med. 36: 181.

that it is almost impossible to raise a calf that has not received any colostrum. If for any reason the young calf does not receive the colostrum, it should be given a teaspoonful of castor oil every two hours until the bowels have moved. Ordinarily, the colostrum should be fed for the first three or four days. It supplies the necessary antibodies or disease-resistant properties which enable the calf to ward off diseases until its own body has had time to establish its own immunity.

Birth Weight

Table LV, compiled at the Missouri Experiment Station shows the average birth weight of calves of different breeds.

Male calves are usually a little larger than female ones. The Missouri Station found that the males weighed from an average of 5 to 8 pounds more than the females. It also found that the first calf of a heifer was somewhat smaller than the average of the breed. On the average, the maximum weight of calves at birth will be between the third and sixth calvings. Old cows seem to have a tendency to drop smaller calves than they did when in their prime.

TABLE LV

Birth Weight of Calves of the Different Breeds *

Breeds	Average Weight		Mature Weight		Weight of Calf in Proportion to Mature Weight of Females, per cent
	Males	Females	Males	Females	
Jersey	60	53	1500	970	5.46
Holstein	95	90	2200	1370	6.57
Guernsey	71	65	1760	1070	6.08
Ayrshire	80	72	1850	1100	6.55
Brown Swiss †	85	80	2000	1300	6.15

* Mo. Exp. Sta. Bul. 336.
† Mature weights of males and all data on Brown Swiss are estimated.

The nutrition of the cow during gestation does not greatly influence the size of the resulting calf. However, if extreme conditions are experienced and continued for a long period of time, they may

prove detrimental, as, for example, when feed from a restricted plant source is given the cow. It is often observed that a cow in very poor flesh will drop a calf of normal size, or a cow in very good flesh will drop a calf that is small for the breed. This can be explained by the fact that the composition of the blood from which the fetus receives its nourishment tends to remain constant even though the food supply is limited. A shortage of any constituent in the blood is made up by drawing upon the reserve supply already in the body. For this reason, the food supply of the fetus remains practically constant even under adverse conditions.

Weaning the Calf.—There has been a great deal of variation in practice regarding the time at which the calf should be taken from the cow. Some successful raisers of calves let the calf nurse but once so that it may receive the colostrum, and then take the calf from the mother and feed it by hand. Others do not allow the calf to nurse even once. Most, however, seem to prefer to leave the calf with the mother for several days or until the milk is good. This seems to be a good practice if the cow is free from disease.

Sometimes, especially with young heifers, the mother's udder is very hard, and the butting which the young calf gives it while nursing seems to be a very helpful treatment for the reduction of the swelling. For this reason, a calf is frequently kept with the dam for some time, the herdsman himself doing part of the milking and allowing the calf to do the rest. The arguments for not allowing the calf to remain with the cow are that the amount of milk which the calf should receive can be better controlled, that there is less difficulty in teaching the calf to drink, and that there is less fretting on the part of both the cow and the calf. The best method, however, seems to be to allow the calf to be with the cow for at least a day or two.

Teaching the Calf to Drink Milk

The longer the calf is nursed by the mother, the harder it is to teach it to drink. By instinct, the calf stretches upward to receive its nourishment. In learning to drink from a pail, however, it must be taught to reach downward. No better method of teaching the calf to drink is known than the simple one of putting one's fingers in its mouth, with one motion bringing head and fingers into a pail con-

taining a small amount of whole milk, and then carefully withdrawing the fingers. It will probably be necessary to crowd the calf into a corner, and to stand astride of its neck, in order to teach it to feed in this way. Some calves learn to drink after the first attempt; with others it is quite a long process. It is usually best to omit the first feeding period as the calf will then be more eager for its milk. It is desirable to use fresh whole milk for this purpose, especially if the calf is young. For the first ten days whole milk is best for the calf.

Amount of Whole Milk to Feed

A calf that weighs 65 pounds or less should receive from 5 to 8 pounds of whole milk per day at first, while a calf weighing over 65 pounds should not receive more than 8 to 10 pounds. As a general rule about 1 pound of milk should be fed for each 10 pounds of body weight. If possible, this amount of milk should be divided into three feeds for the first week. During the second week the amount can be increased slightly, if the calf remains healthy. After about ten days or two weeks, the food of the calf may be changed to skimmilk or some other milk substitute if the owner so desires.

Utensils

Under any system of feeding, it is essential that all the utensils which are used in the feeding of the calf be kept clean. Pails should be of metal with well-soldered seams, so that milk will not lodge, thereby furnishing food upon which bacteria may thrive. The pails or mangers in which the grain and silage are fed must also be kept perfectly clean. The pails in which the milk is fed should be washed and, if possible, sterilized after each feeding. Many of the disorders of the digestive system of calves can be traced to dirty utensils. Wooden utensils are very difficult to keep clean. Too much care cannot be taken in order to have clean pails.

Methods of Raising Calves

Usually, whole milk is too expensive to feed to calves after they are ten days or two weeks old. Some dairymen, however, prefer to

use whole milk, thinking they can raise better calves with less trouble. In many sections of the country where cream or butter is sold, plenty of skimmilk is available for calf raising. Farmers thus situated are fortunate, and do not have a very serious problem in raising their calves. In other sections, where whole milk is sold from the farm and hence very little skimmilk is available, the raising of calves is somewhat of a problem. Several different methods of calf feeding have been devised for such farms. These consist of raising calves on some milk substitute, or of giving them a good start on whole milk or skimmilk and then raising them on grain and hay. Sometimes whey or buttermilk is available and is fed to calves.

Raising Calves on Whole Milk.—Calves should be given whole milk for the first ten days or two weeks. It is usually too expensive to continue the feeding of whole milk for a longer period as good calves can be grown on skimmilk. When whole milk is fed, calves should be taught to eat hay and grain at an early age so that they can be weaned from whole milk as soon as possible. Whole milk diluted with water so that it has the same fuel value as an equal quantity of skimmilk is also more expensive than feeding skimmilk, although good calves can be raised by this method.

Using Nurse Cows.—Sometimes hard milking, low-testing, or kicking cows can be used as nurse cows with good success. From 2 to 4 calves of about the same age and vigor can be turned in with one cow and allowed to compete for the milk. Care should be taken that there are about the right number of calves on the cow. If there are too many they will not receive sufficient feed; if there are not enough, they will consume more than is necessary. They should be given hay and grain at an early age, so they can be removed from the cow at two to three months of age. The cow can nurse several sets of calves during her lactation. This method requires little labor but difficulty is sometimes experienced, especially in small herds, in having the correct number of calves available at times when required.

Raising Calves on Farms Where Skimmilk, Buttermilk, or Whey is Available.—Table LVI shows the average composition of whole milk, colostrum milk, skimmilk, buttermilk, and whey:

TABLE LVI

AVERAGE COMPOSITION OF WHOLE MILK, COLOSTRUM MILK, SKIMMILK, BUTTERMILK, AND WHEY *

	Water, per cent	Ash, per cent	Fat, per cent	Protein, per cent	Sugar or Carbo-hydrates, per cent
Whole milk	87.0	0.7	4.0	3.3	5.0
Colostrum milk	74.5	1.6	3.6	17.6	2.7
Skimmilk	90.5	0.7	0.3	3.4	5.1
Buttermilk	91.0	0.8	0.5	3.5	4.2
Whey	93.4	0.7	0.3	0.8	4.8

* Mo. Res. Bul. 35.

As noted above, the only apparent difference between skimmilk and whole milk is that the fat has been removed from the former, but with the fat vitamins A and D are also removed. Substitutions can easily be made for the fat and vitamins, and just as good calves can be raised on skimmilk as those raised on whole milk or those allowed to run with the dam. The calves may not be so fat and thrifty looking, but they will grow into just as large and productive cows.

Changing to Skimmilk.—Calves that are to be raised on skimmilk should be fed on whole milk for the first ten days or two weeks, and, if the calf is not thrifty, even longer. The change should not be made until the calf is growing vigorously. The transition period from whole to skimmilk should require about a week. For the first day or two, about a pound of skimmilk should be substituted for an equal amount of the whole milk, and later a gradually increasing amount up to 2 pounds. If whole milk is very valuable and the calves very thrifty, the change can be made in four or five days if attention is given to details.

After the change has been made, the amount of skimmilk should be gradually increased as the appetite of the calf indicates, until 16 to 18 pounds is being fed. With large thrifty calves, as much as 20 to 24 pounds of skimmilk may be fed, but unless skimmilk is very plentiful this is not necessary. Usually 16 to 20 pounds is the

maximum amount which is fed. Probably more calves die from the effects of overfeeding than from any other single cause. This is due to the fact that most feeders, instead of weighing or measuring the amount to be fed, guess at it, and as a result there is a great variation in the amount which the calf receives from day to day. As a consequence, the calf is often overfed. It is a good rule always to keep the calf a little hungry.

Temperature and Quality of Milk.—The temperature of the milk is also a very important consideration, especially for young calves. The skimmilk should be heated to about the temperature of milk

FIG. 38.—A group of healthy Ayrshire calves on Auchenbrain farm in Ayr (*Anthony*).

fresh from the cow, approximately 100° F. It is always well to use a thermometer to test the temperature. Judging by means of the finger is not sufficiently accurate to be relied upon. When the calf is two or three months old, it is not so necessary to heat the milk although even then calves can be raised with less trouble if the milk is heated. Giving the calf warm milk at one feeding and cold milk at the next is very likely to upset its digestion.

It is always best to feed the skimmilk when it is fresh. There is no easier way to upset the digestive system than to feed sweet milk at one feeding and sour milk at the next. Sour milk can be fed suc-

cessfully to calves if care is taken to see that it is always uniform in quality.

If the skimmilk is obtained at the creamery, it is very necessary that it be pasteurized before being fed to calves. Otherwise the milk may carry disease germs which might infect the herd. Most states have laws requiring such milk to be pasteurized.

The skimmilk may well be fed for the first six months and, if the supply warrants, for an even longer period.

Concentrates with Skimmilk.—Since the fat has been removed from the skimmilk, it is necessary that some grain, or grain and hay, be fed as soon as the change is made. Calves should be taught to eat grain as soon as they have been weaned from whole milk, to take the place of the nutrients removed when the milk is skimmed.

Many grain mixtures have been proposed for dairy calves, although the kind of grain fed is not very important. It has been found that almost any combination of grains may be fed successfully. The principal necessity is to supply the nutrients which have been removed in the fat of the skimmilk. The ration need not contain a high-protein feed if a legume hay is fed, since the protein of the milk has not been removed.

In the sections where corn is plentiful, it may be used as the basis of the ration. It is desirable, however, when timothy hay is used for a roughage, to have some linseed meal in the ration. The following grain mixtures have been used with good results:

MIXTURE 1

3 parts corn meal
3 parts ground oats
1 part linseed meal
1 part wheat bran

MIXTURE 2

2 parts wheat bran
2 parts ground oats
1 part oil meal

MIXTURE 3

3 parts corn meal
1 part wheat bran

Though it is customary to grind the grain for calves, it is not absolutely necessary. They seem to prefer the whole grains. Until the calf is six months old, it need not be fed more than 3 pounds of grain daily.

Hay with Skimmilk.—Usually when a calf is about ten days old it will begin to nibble hay and grain when these are offered to it. The amount first eaten is, of course, small, but should be increased as the calf grows older.

The hay should be bright and clean. Care should be taken at this time to prevent the calf from eating anything that is moldy or coarse. The hay may be either fine-grade timothy, clover, or alfalfa. Well-cured legume hay is to be preferred, since it is much richer in protein, vitamins, and minerals than the non-legumes. The quality of the hay is an important consideration, especially during the first six months of the calf's life. The importance of good hay in the calf's ration is largely because of its content of vitamins A and D. If the hay is of poor quality, trouble may be experienced because of the lack of these vitamins, unless cod-liver oil is added to the ration. The calf should be allowed to eat as much hay as it will. By the time it is six months old it should be eating 3 to 4 pounds daily.

Succulence with Skimmilk.—There seems to be no benefit from feeding silage to calves before they are two months of age, as it is not so rich in vitamins and minerals as well-cured legume hay. After that age they may be fed silage in limited amounts along with hay. A calf at six months of age will eat from 3 to 5 pounds of silage per day. Roots can be fed but are usually more expensive than silage.

Vitamins and Minerals with Skimmilk.—Dairy calves when fed skimmilk, along with an abundance of well cured legume hay, will probably not suffer from a lack of minerals or vitamins. Skimmilk is a rich source of both calcium and phosphorus and well cured hay when fed in fairly large quantities will provide sufficient Vitamin A and D. If, however, a poor grade of hay is fed, some vitamin supplement such as one of the cod liver oil concentrates should be provided.

Feeding Schedule for Skimmilk Calves.—The following feeding schedule has been arranged as a guide for the feeding of calves on skimmilk:

TABLE LVII

DAILY FEEDING SCHEDULE FOR SKIMMILK-FED CALVES

For Jerseys, Guernseys, or Ayrshires

Age of Calf	Whole Milk, lb.	Skim Milk, lb.	Grain, lb.	Hay, lb.
1 to 3 days	with dam			
3 to 14 days	6 to 9			
2 to 3 weeks	9 to 1	1 to 9	$\frac{1}{8}$	all will eat
3 to 4 weeks	....	10	$\frac{1}{4}$	
4 to 5 weeks	....	11	$\frac{1}{2}$	
5 to 6 weeks	....	12	$\frac{3}{4}$	
6 to 8 weeks	....	13	1	
8 to 12 weeks	....	14	2	
12 to 24 weeks	....	16	3	

For Holstein, Brown Swiss, or Shorthorn

Age of Calf	Whole Milk, lb.	Skim Milk, lb.	Grain, lb.	Hay, lb.
1 to 3 days	with dam			
3 to 14 days	9 to 11			
2 to 3 weeks	11 to 1	1 to 11	$\frac{1}{8}$	all will eat
3 to 4 weeks	....	12	$\frac{1}{4}$	
4 to 5 weeks	....	14	$\frac{1}{2}$	
5 to 6 weeks	....	15	$\frac{3}{4}$	
6 to 8 weeks	....	15	1	
8 to 12 weeks	....	16	2	
12 to 24 weeks	....	16 to 20	3	

It has been calculated that it requires the following amount of feed to raise a calf to six months of age:

	Pounds
Whole milk..........................	90 to 200
Skimmilk..........................	2300 to 3000
Grain..........................	150
Hay..........................	500

Whey and Buttermilk for Calves.—The analysis of buttermilk, as shown in Table LVI, is very similar to that of skimmilk, and so the same supplements that are used with skimmilk can be successfully used in raising buttermilk calves. On most farms, how-

ever, where buttermilk can be secured skimmilk is also available, and as a rule it will be found that sweet skimmilk grows a better and thriftier calf than buttermilk. Some experiments, however, show that calves fed buttermilk are less subject to scours than those fed skimmilk.

Whey has a higher percentage of water and a much lower amount of protein, but about the same amount of fat and sugar, as skimmilk. If whey is to be fed, the grain mixture must have a high protein content. Linseed meal is often mixed as a gruel in the whey. If whey must be fed, it should not be fed until the calf is five or six weeks old; and even then great care must be taken to prevent digestive trouble. After that age good calves can be raised on whey if it is properly supplemented and the calves are given good care.

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LECTURE XX

RAISING THE DAIRY CALF (*Continued*)

Raising Calves on Farms Where Skimmilk is Not Available

Milk Gruels or Milk Substitutes.—For many years, first in England and later in the United States, calves have been raised on so-called milk substitutes. The need for such a feed came as a result of the demand for whole milk around the cities, so that no skimmilk was available. At first no calves were raised under such conditions, but later several commercial calf meals appeared on the market, and later several home-made mixtures were recommended which have given fairly good results. Some of the first commercial mixtures did not prove satisfactory, but some of the later ones have been excellent. Greater care must be exercised in feeding calves on these substitutes than in feeding them on skimmilk, but with precautions they are successful.

These feeds were prepared in the form of gruels as it was thought that calves would do better if the feed was in the same form as milk. Later it has been found that calves can eat dry meal and make just as good growth with less labor than if it is made into a gruel. Several satisfactory calf meals have been developed, but the trouble with most of the home-made mixtures is that often many of the ingredients are high in price and, moreover, cannot be readily obtained by all dairymen. The Purdue Experiment Station,[1] however, recommended a calf meal which was both cheap and easy to obtain. It has been used extensively and has given good results. The formula is as follows:

Purdue Calf Mixture

Hominy feed	Equal parts by weight
Linseed meal	
Red Dog flour	
Dried blood	

[1] Purdue Exp. Sta. Bul. 193.

Linsey, of the Massachusetts Experiment Station,[1] recommended a ration which has given good results. It is as follows:

LINSEY'S CALF MEAL

22 lb. ground oat flakes
10 lb. flaxseed meal
5 lb. flour middlings
11 lb. fine corn meal
1½ lb. prepared blood flour
½ lb. salt

The New York (Cornell) Station[2] has recommended one with the following formula:

CORNELL CALF MEAL

25 lb. yellow corn meal
15 lb. oat flour or ground oats
10 lb. malted barley or ground barley
22 lb. Red Dog flour or flour middlings
15 lb. linseed meal
10 lb. soluble blood flour
1 lb. precipitated bone meal
1 lb. precipitated calcium carbonate
1 lb. salt

Many other formulas have been more or less successful.

Preparing the Feed.—It is necessary that the meal be very finely ground and that it contain very little fiber, otherwise it will not dissolve well in the water and the calves will not consume it all. Generally, 1 pound (dry weight) of a calf meal is a fair substitute for 4½ quarts or about 9 or 10 pounds of skimmilk. In mixing it, the meal should be made in a gruel or thick paste by adding a small quantity of cold water and stirring until all the lumps are gone. After this, boiling water or very hot water should be added at the rate of 4½ quarts for every pound of meal used. It is a good plan to heat this mixture to 145° F. for thirty minutes and then to cool to about 95° F. before feeding. This mixture can be substituted for skimmilk pound for pound.

Schedule for Feeding Calf Meals.—The feeding schedule, Table LVIII, may serve as a guide for the feeding of calves on calf meal.

[1] Mass. Exp. Sta. Bul. 164.
[2] Cornell Exp. Sta. Bul. 439.

Gruel feeding may be discontinued after the fourth month if desirable, as a calf can be grown very satisfactorily on grain and hay after reaching that age.

As a rule, the calves will not be as fat and thrifty looking when fed on calf meals as when fed on milk, nor will they be as well grown; but if they are fed carefully after being taken off the calf meal they will make just as large and thrifty cows. However, a calf meal to be successful must be made up of ingredients which are easily digested, which contain the necessary vitamins and minerals, and which are fairly cheap and easily obtainable.

TABLE LVIII

DAILY FEEDING SCHEDULE FOR CALVES FED CALF MEAL

Age	Pounds Milk, Daily	Pounds Gruel, Daily	Pounds Grain, Daily	Pounds Hay, Daily
1 to 3 days	with dam			
3 to 14 days	10			
2 to 3 weeks	9	1	$\frac{1}{8}$	all will eat
3 weeks to 1 month	9	3	$\frac{1}{4}$	all will eat
1 month to $1\frac{1}{2}$ months	6	6	$\frac{1}{2}$	all will eat
$1\frac{1}{2}$ months to 2 months	......	12	$\frac{3}{4}$	all will eat
2 to 3 months	......	14	1	all will eat
3 to 4 months	......	14	2	all will eat
4 to 5 months	......	......	4	all will eat
5 to 6 months	......	......	$4\frac{1}{2}$	all will eat

Feeding a Minimum Amount of Milk with Grain and Hay.—A method of raising calves which has been tried at several of the experiment stations with good results is to give them a good start on either whole milk alone or whole milk and skimmilk, and at the end of about two months have them changed to grain and hay. The object of this method is to use a minimum amount of milk and at the same time grow good healthy calves. This method also has the advantages that the grain ration need include only the common feeds which are available to all farmers and that the ration can be prepared easily and fed dry. The secret of success with this method

is to give the calves a good start before they are weaned from the milk.

Method of Feeding.—At the Missouri Station [1] it was planned to get the calves on a good ration of skimmilk, with some hay and grain, as soon as possible. They were fed whole milk for the first two weeks, and then, if skimmilk was available, it was substituted gradually. If skimmilk was not available the whole milk was continued. The calves were fed from 12 to 15 pounds of milk daily, depending upon their size and condition.

The calves should be taught as soon as possible to eat grain and hay, which should be fed liberally. At the Minnesota Station [2] the grain fed during the first few weeks was either cracked corn or crushed oats or a mixture of the two. Later, a mixture of 4 parts corn meal, 1 part wheat bran, and 1 part linseed meal was used. The hay should be a legume hay of good quality.

Ordinarily, a calf can be raised by this method with as little as 200 pounds of whole milk and 600 pounds of skimmilk. The amount consumed by the calves at the Minnesota Station is given in Table LIX.

TABLE LIX

AVERAGE FEED CONSUMED AT 180 DAYS OF AGE

Group	Breed	Age of Weaning, days	Whole Milk, lb.	Skim Milk, lb.	Grain, lb.	Hay, lb.
1	Grade Holstein	72	864	......	555	263
2	Grade Holstein	50	442	......	528	279
3	Pure-bred Jersey	72	572	......	397	309
4	Grade Guernsey	70	449	88	412	295
5	Grade Holstein	60	166	378	476	385

The five groups of calves as shown were raised by feeding either whole milk or whole milk and skimmilk along with grain and hay ranging from 50 to 72 days, after which they were fed only hay and grain. Table LX shows the average weight of the groups as

[1] Mo. Exp. Sta. Circ. 88.
[2] Minn. Spec. Bul. 91.

TABLE LX

RECORD OF GROWTH OF CALVES FED MINIMUM AMOUNT OF MILK

Group	Number of Calves	How Fed	Length of Time Fed Milk, days	Weight at End of Feeding, per cent normal	Weight at End of 180 Days, per cent normal
1	4	Whole milk Grain and hay	72	100.2	94.5
2	3	Grain and hay	50	98.7	91.3
3	2	Grain and hay	72	89.0	85.0
4	6	Whole milk Skim milk Grain and hay	70	107.0	92.3
5	3	Grain and hay	60	102.0	90.3

compared with normal weight, at the end of the milk-feeding period and at the end of 180 days, when fed as in previous table.

This method offers to the dairyman with a small amount of available milk a cheap, efficient, and easy way to raise his dairy calves.

Feeding "Calf Starters."—Several experiment stations have recommended special mixtures that can be fed to young calves to give them a good start with only a limited amount of whole milk. These mixtures are fed dry along with hay and grain but include some rich protein feed of animal origin which seems to increase the gain somewhat and at the same time decrease the amount of milk needed. The "starter" is continued until the calf has a good start (three or four months), when it is discontinued and the calves are put on cheaper grain mixture.

These calf starters usually contain blood flour or skimmilk powder or a combination of the two. They are always mixed with other grains and fed dry.

New Jersey Calf Ration.[1]—The New Jersey Calf ration has been used extensively with very good results. Often as little as 150 pounds of whole milk is required, and calves can be grown to

[1] N. J. Ext. Bul. 73.

normal size. Beginning the second week, the feeding of the grain mix and alfalfa hay along with whole milk is recommended. On the fourth week the milk is diluted with water so that by the time the calf is 30 days of age it is receiving only water, dry mix, and hay. The ration is as follows:

New Jersey Calf Ration

100 lb.	yellow corn meal
150 lb.	ground oats
50 lb.	wheat bran
50 lb.	linseed oil meal
50 lb.	soluble blood meal
4 lb.	steamed bone meal
4 lb.	finely pulverized limestone
4 lb.	salt

The calf should be given all the grain mixture it will eat up to a maximum of 6 pounds per day, and the ration is discontinued when the calf is six months of age.

Penn State Calf Ration.—A ration that contains both soluble blood flour and skimmilk powder has been recommended by the Pennsylvania Experiment Station. It is as follows:

Penn State Calf Mixture

20 per cent	yellow corn meal
10 per cent	wheat bran
25 per cent	ground oats
15 per cent	linseed oil meal
2 per cent	blood flour
25 per cent	skimmilk powder
2 per cent	bone meal
1 per cent	salt

This is fed similarly to the New Jersey ration until the calf is twelve weeks of age, after which the skimmilk powder may be omitted from the ration.

Reinforced Calf Starter.—The New York (Cornell) Experiment Station [1] has determined that not more than 22 per cent of dry skim-

[1] Cornell Exp. Sta. Bul. 622.

milk is necessary in a calf starting ration. However, they found that, when the calves are kept continuously stabled until they are six months of age, they need more protection against back weakness than is given by 22 per cent skimmilk powder and hay. They therefore recommend the addition of 0.25 per cent reinforced cod-liver oil. In order to protect against back weakness they recommend the following ration:

REINFORCED CALF STARTER MIXTURE

32.25	per cent yellow corn meal	20	per cent dry skimmilk
28	per cent rolled oats	0.5	per cent salt
10	per cent wheat bran	0.5	per cent ground limestone
5	per cent linseed meal	0.5	per cent steamed bone meal
3	per cent white fish meal	0.25	per cent reinforced cod-liver oil

Dry Skimmilk, Dry and Semi-solid Buttermilk.—Sometimes it is almost impossible, or at least very inconvenient, for the dairyman selling his milk to provide even a small amount of skimmilk for calf feeding. It has been found that skimmilk powder, buttermilk powder, or semi-solid buttermilk can be substituted for skimmilk. Dried skimmilk is perhaps the most satisfactory. When being prepared, it should first be made into a thick paste with water and stirred until all the lumps are eliminated. It can then be mixed with warm water, in the proportion of 1 part of the powder to 9 parts of water, and fed in the same way and in the same amounts as ordinary skimmilk. In fact, it can be fed alternately with ordinary skimmilk without in any way affecting the digestive system of the calf. This is an advantage to the dairyman who may have a surplus of milk at one time and a shortage at other times, since he can keep some dried skimmilk for periods of shortage.

Powdered buttermilk can be used in the same way, but greater care is required in starting the calves on it, on account of its acidity. Semi-solid buttermilk can also be used, but it is not as satisfactory as the dried, especially in the summer, since it will not keep as well. It should be mixed with about three times its weight of warm water.

These products are usually higher in price than skimmilk but not as high as whole milk.

Other Details in Calf Feeding

Feeders.—Hooper[1] found that calves fed through the nipple were more thrifty than those fed in the bucket, up to the age of seventy days. After this age there was very little difference. Hayward seems to favor the use of the calf feeder in feeding milk substitutes. In general, however, it should be stated that calf feeders are difficult to keep clean and are often out of repair. There seems to be very little real use for them.

Salt and Water.—Most feeders add some salt to the grain ration. The demand for salt, however, is not great up to the time the calves reach the age of six months. When receiving an ample supply of skimmilk, calves usually have little need for additional water. However, unless the amount of skimmilk fed is adequate to supply their requirements for water, they should be supplied with additional water. When the calves are on dry feed the need of water is apparent. Water must be supplied in adequate amounts, and probably the best way to furnish it is by means of water cups where the calves can supply themselves according to their desires. Calves seem to differ greatly in the amount of water consumed. Heifers kept under the same conditions and fed the same rations have been known to vary as much as 40 to 50 pounds per day in their water consumption.

Stalls and Ties for Calves.—When the new-born calf is removed from the mother it should first be put in a small box stall by itself. This stall should not be more than 4 or 5 feet square. Thus isolated, the calf can be taught to drink and kept from sucking other calves. Some dairymen prefer to keep their calves in such stalls permanently as a protection against disease. It is more usual, however, after the first week or ten days, to keep several calves together in a larger box stall. This stall should be provided with stanchions so that the calves can be tied while being fed, to insure each one's getting its proper amount of feed. Each calf should be fed individually, as some are fast feeders and others are slow. The feeding of all calves in a trough should never be practiced.

[1] Ky. Exp. Sta. Bul. 171.

Keeping Pens Clean.—Calves should always have clean pens. A great deal of liquid is excreted by a calf, and hence the bedding should be taken into consideration. Any kind of clean bedding is suitable if it is provided in sufficient amounts. Care should always be taken that the corners of the pens are thoroughly cleaned out.

It is also advisable to give the pens a thorough cleaning and disinfecting every few weeks. Whitewash is one of the best disin-

FIG. 39.—Clean, well-bedded pens are essential in calf raising.

fectants. It can be applied either with a spray pump or with a whitewash brush. Another disinfectant is a 5 per cent solution of crude carbolic acid. Creolin or lysol can be used in 3 to 5 per cent solutions and are also satisfactory disinfectants.

Exercise.—Calf pens should be provided with exercise yards. Although the young calf does not require a large amount of exercise, still it should have a place of sufficient size for that purpose. Direct sunlight, as has already been noted, is an effective aid in

preventing rickets, so that for calves two months of age it is well to provide some clean pen into which they are turned on sunny days. The yard should also be provided with shade. A well-shaded

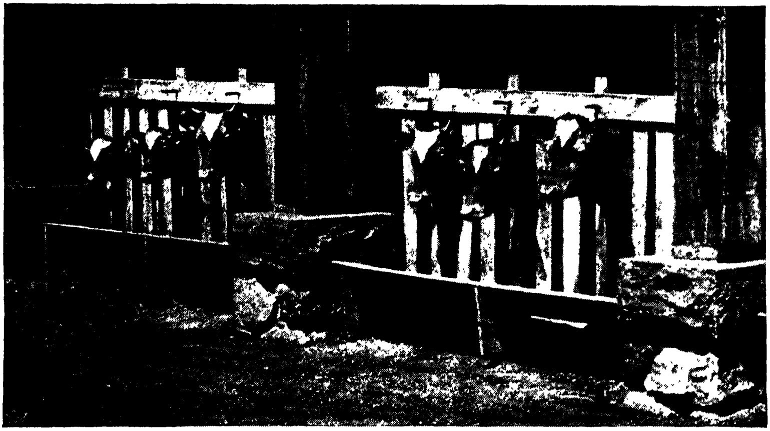

FIG. 40.—Calves should be fastened when being fed.

pasture, near the buildings, in which the calves can graze and also exercise, is valuable. Stanchions can be erected in the pasture and the calves fed there. Pasture need not be furnished until the calves

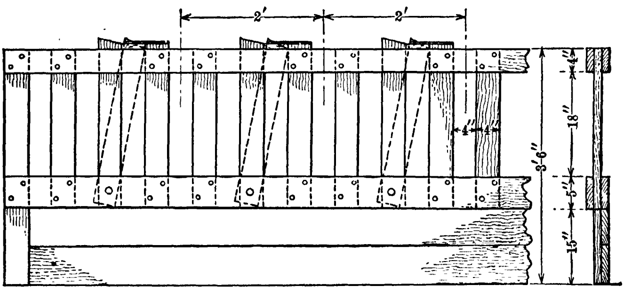

FIG. 41.—Plans for wooden stanchions for calves.

are six months of age, but good thrifty calves will do well on pasture after they are three or four months of age.

Fall or Spring Calves.—The fall calf is fed milk, or whatever is used instead, until spring, and then is turned out to pasture.

The spring calf is changed from milk to dry feed during the first winter of its life and does not make quite as good or as cheap gains as the fall calf. After the fall calf goes on dry feed it has only one winter feeding to go through before freshening, whereas the spring calf has two. As a general rule, it is cheaper both in feed and labor to keep the calf on pasture as much as possible. For this reason the expense of raising the spring calf is greater than that of raising a fall heifer. Many dairy farmers, however, must have cows freshen the year around and so, of course, must raise spring calves as well as fall calves.

Veal Production

The breeder of pure-bred stock is generally able to find a market for his surplus animals, but the man who keeps grades must dispose of his surplus calves. Many are sold at birth, but in some states it is against the law to kill calves for veal under a certain age. The meat from a calf killed for veal at a very early age is known as "bob veal." A calf that is over the age for good veal and has not received milk for some time is known as a "heretic."

If milk is not worth too much, calves may be raised for veal. In general, where whole-milk feeding is practiced in raising veal, 10 pounds of whole milk is required to produce 1 pound of veal. The market seems to demand veal from four to eight weeks old and from 150 to 175 pounds in weight. Whether it will pay to raise veal, then, depends not only upon the cost of milk and the price of veal but also upon the initial size of the calf. For example, a calf that weighed 100 pounds at birth would need to gain only 50 pounds to reach the desired 150 pounds. This would require around 500 pounds of milk. A calf weighing 60 pounds at birth would need to gain 90 pounds to reach the weight of 150 pounds, and the amount of milk required would be 900 pounds. Thus the latter calf would require almost twice as much milk as the first calf to reach the required size.

Table LXI shows the results of some veal experiments conducted at the Pennsylvania Experiment Station.[1]

[1] Pa. Exp. Sta. Rept. 1916–1917, p. 337.

TABLE LXI

RESULTS OF THE VEAL PRODUCTION EXPERIMENT

Ration	Number of Calves	Average Number of Days Fed	Average Weight at Beginning, lb.	Average Weight at End, lb.	Average Gain Daily, lb.	Average Profit above Feed
Whole milk, dark stall	3	49	104	212	2.20	$4.10
Whole milk, nurse cow	3	59	75	179	1.69	0.26
Whole milk, ordinary stall.	2	67	65	129	0.88	−4.10
Blatchford's calf meal	3	60	88	147	0.96	3.79
Schumaker's calf meal	3	58	86	151	1.24	1.16
Skimmilk and grain. . .	2	65	63	137	0.96	2.91

Table LXII, prepared by Bechdel, shows the average returns at the different prices of milk and veal.

TABLE LXII

AVERAGE RETURN AT VARIOUS PRICES OF MILK AND VEAL

Milk per Cwt.	Price of Veal per 1 Pound Live Weight								
	$0.24	$0.20	$0.18	$0.16	$0.14	$0.12	$0.11	$0.09	$0.08
$1.40	. . . .	. . . .	$19.94	$16.34	$12.47	$9.13	$7.33	$3.27	$1.93
1.60	. . . .	. . . .	18.16	14.56	10.95	7.35	5.56	1.94	0.14
1.80	. . . .	. . . .	16.38	12.77	9.17	5.56	3.76	0.16	−1.65
2.00	. . . .	. . . .	14.59	10.99	7.34	3.33	1.98	−1.63	−3.43
2.20	. . . .	$16.41	12.81	9.20	5.60	2.09	0.19	−3.41	−5.21
2.40	. . . .	14.63	11.02	7.42	3.81	0.21	−1.59	−5.20	−6.99
2.60	$20.05	12.84	9.15	5.64	2.03	−1.51	−3.37	−6.99	−8.78
2.80	18.26	11.06	7.45	3.85	0.25	−3.36			
3.00	16.48	9.28	5.68	2.08	−1.53				
3.40	12.92	5.72	2.11	−1.49					

When the cost of milk is low and the price of veal is high, there may be considerable profit in raising calves for veal.

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LECTURE XXI

CARE AND DEVELOPMENT OF THE DAIRY HEIFER

Growth

Growth is one of the oldest of phenomena, yet we have hardly begun to understand the principles underlying it. Growth [1] has been defined as the increase in volume in a living material.

It is the result of three processes, namely, multiplication of cells, enlargement of cells, and deposition of intercellular substance, the first two being more potent than the third. Minot [2] states that the impulse to grow is imparted at the time of fertilization of the ovum and that the growth of the germ of the animal, from the time of fertilization to that of birth, represents an increase of over 5,000,000 per cent, the gain at first being 1000 per cent in a day. He calculated that 98 per cent of the growth impulse is used up at the time of birth.

Causes of Growth.—Just as there are two factors related to milk production, so there are two factors related to growth, one internal and the other external. It has been observed that animals will often continue to grow even under adverse conditions of nutrition. The impulse to grow, which is set free at the fertilization of the ovum, will continue until the full size has been reached unless adverse conditions are encountered. The cause of this growth stimulus is thought to be the hormones or secretions of the endocrine glands. The endocrine glands which are thought to be related to growth are the pituitary body, the thyroid gland, the thymus gland, the suprarenal body, the pineal body, and the ovaries and testes. The internal factors are not under the control of the feeder to any great extent, and they will continue to act even under adverse conditions. They seem to influence the growth of the skeleton to a

[1] Experimental Zoology, Morgan.

[2] The Problem of Age, Growth, and Death, Minot.

greater extent than growth of the fleshy part of the body. The skeleton has a stronger tendency to grow than the fleshy part. Waters[1] found that animals that were fed even less than a maintenance ration continued to make skeleton growth for six months while the fleshy part did not gain to any extent.

The external factors depend upon the nutrition and handling of the animal; that is, they are dependent upon conditions under the herdsman's control. If calves are not supplied with all the nutrients necessary for growth they will fail to reach their full size.

Limits of Growth.—It is thought[2] that the variation in the growth of different animals is largely inherited. In other words, an animal inherits the capacity to reach a certain size if given favorable conditions, and it will not grow any larger even under the most favorable conditions of care and feed. However, if the conditions are adverse, the animal may never reach this maximum size. Animals are able to overcome adverse conditions, however, if not continued for too long a time and not too severe. It has been shown[3] that, after a period of retarded growth, calves will grow at a faster rate than normal when the conditions are again improved, and will continue to grow for a longer period of time. This may compensate for the loss due to retarded growth unless the retardation is continued for too long a time.

Measuring Growth.—Since the fleshy part of the animal does not gain at the same rate as the skeleton, it can be seen that growth cannot be measured by the weight alone. Eckles[4] decided, after a study of several measurements, that the height at the withers would be the easiest and most satisfactory measure of the growth of the skeleton. Thus two units are commonly used for measuring growth, gain in live weight and gain in height at the withers.

Normal Growth.—In order to obtain information on the weight and height at withers of heifers fed according to good dairy practice, all calves and heifers at the Missouri Station were weighed and measured. From the data collected, together with similar data collected from other sources, a normal growth table for the Holstein,

[1] Soc. Prom. Agr. Sci. 29.

[2] Biochem. Bul. 3 : 156.

[3] Mo. Res. Bul. 31.

[4] Mo. Res. Bul. 36.

Jersey, Aryshire, and Guernsey breeds was formulated.[1] This is given in Table LXIII.

TABLE LXIII

NORMAL GROWTH IN WEIGHT AND HEIGHT OF DAIRY HEIFERS

Age Month	Ayrshire		Holstein		Jersey		Guernsey	
	Weight, lb.	Height at Withers, in.	Weight, lb.	Height at Withers, in.	Weight, lb.	Height at Withers, in.	Weight, lb.	Height at Withers, in.
Birth	72	27.6	90	29.1	53	25.7	65	26.6
1	89	28.6	112	30.6	67	27.0	77	28.2
2	119	30.2	148	32.3	90	28.9	102	29.8
3	158	31.9	193	34.3	121	30.6	133	31.6
4	198	34.0	243	36.2	158	32.6	173	33.5
5	245	35.5	297	37.7	199	34.5	216	35.3
6	293	37.2	355	39.7	243	36.2	260	36.9
7	344	38.5	410	41.1	286	37.7	305	38.4
8	389	39.9	462	42.3	324	39.0	350	39.9
9	433	40.9	509	43.5	360	40.1	389	40.9
10	469	41.7	552	44.4	393	40.9	427	41.7
11	502	42.5	593	45.3	420	41.7	459	42.6
12	538	43.2	632	46.0	450	42.2	490	43.3
13	577	44.0	671	46.7	479	42.8	524	43.9
14	611	44.8	705	47.3	507	43.3	556	44.6
15	638	45.1	746	47.9	530	43.9	584	45.0
16	669	45.7	782	48.5	558	44.4	605	45.3
17	697	46.2	809	48.9	580	44.7	634	45.9
18	725	46.5	845	49.3	601	45.2	663	46.4
19	758	46.8	878	49.8	622	45.5	686	46.7
20	793	47.4	912	50.2	642	45.9	712	47.0
21	818	47.6	952	50.6	665	46.2	737	47.3
22	844	47.8	986	51.0	684	46.4	763	47.7
23	871	48.1	1024	51.3	708	46.7	788	47.9
24	902	48.3	1069	51.7	733	46.9	818	48.0
30	945	48.3	1120	52.5	824	47.9	880	49.3
36	968	48.7	1165	53.0	855	48.2	901	49.9
48	1035	50.2	1232	53.3	897	48.5	990	50.4
60	1080	50.4	1330	53.6	937	49.0	1055	50.6
96	1143	49.2	1365	53.2	909	47.7	1070	49.6

[1] Mo. Exp. Sta. Bul. 336.

This table can be used by breeders to determine whether or not their calves and heifers are growing normally. If scales are at hand the calves or heifers can be weighed at intervals, and their height at withers can easily be determined.

Table LXIII also shows that there is a distinct difference between the different breeds in the time that their skeleton growth is complete. The Jersey has practically its full skeleton growth at the age of four years, but the Holstein continues to grow in skeleton until it is almost five years of age. The other breeds mature at ages between these two extremes. The growth in the fleshy part, as denoted by weight, does not reach its maximum until about two years after the skeleton has ceased to grow.

Feeding the Dairy Heifer

There is not complete unity of opinion as to the best manner in which to feed dairy heifers. After the heifer is past the danger stage that is always present with young calves, and before she has reached a productive stage, the tendency has been to rough her through with as little care and feed as possible. Before taking up the method of feeding, it is necessary to understand the effects of nutrition during this period upon the growth of the dairy heifer; upon her dairy type, upon her sexual maturity, and upon the other factors that may affect her future usefulness.

Effect of Ration upon Growth and Size of Animal.—Several studies have been made upon the development of heifers during the period from the age of six months to freshening time. One of the most extensive was carried on at the Missouri Experiment Station.[1] It covered a period of eight years and entailed forty animals. The heifers were divided into two main groups. One group was fed skimmilk for the first six months, and all the grain and hay they would consume from birth until the time of first calving; the other group was fed skimmilk for the first six months, and then only pasture or hay until the time of first calving. Weights and measurements were taken monthly. Half of each group were bred early and the other half were bred late, so that data in regard to breeding could be obtained.

[1] Mo. Exp. Sta. Bul. 135 and Mo. Res. Bul. 31.

During the growing period the heavy ration caused a much more rapid growth, both in skeleton and in flesh, especially during the months of rapid development. Later, the heifers fed the heavy ration became much fatter. Those fed the light ration grew less rapidly but continued to grow for a longer period of time, never, however, reaching the size of the heavily fed group. The weights always showed a much greater difference than the skeleton measurements.

Table LXIV compares the effect of rations upon skeleton growth and increase in weight in percentage of normal.

TABLE LXIV

THE EFFECTS OF RATION UPON GROWTH AND WEIGHT OF HEIFERS IN PERCENTAGE OF NORMAL

	Jerseys		Holsteins	
	Light Fed	Heavy Fed	Light Fed	Heavy Fed
Months	Weight	Weight	Weight	Weight
6	95	99	85	120
12	80	104	73	118
18	83	128	84	130
24	84	109	88	119
	Height	Height	Height	Height
6	98	99	96	102
12	95	101	93	103
18	95	102	95	103
24	96	101	97	103

Effect of Rations Fed during the Winter on Summer Gains.—Heifers that have been fed heavily during the winter and are then turned out into a pasture in summer usually make much smaller gains during the summer than those that have been fed lightly. In experiments at the West Virginia Station[1] the tendency was for both the heavily and lightly fed groups to approach normal during

[1] W. Va. Exp. Sta. Bul. 232.

the summer months. This would indicate that little is to be gained by too heavy feeding during the winter months if the heifers are to be pastured during the summer.

Effect of Ration on Dairy Type.—During the growing period, the Missouri Experiment Station found that heavy rations tended toward the development of larger and somewhat coarser animals than lighter rations. When the heifers were placed on the same ration after freshening, however, the difference disappeared.

Effect of Ration on Dairy Qualities.—The Missouri experimenters found some high-producing cows in each group, also some medium producers and some inferior producers. Heredity exerts a stronger influence upon the dairy cow's production than the ration does, but the data show that the heifers receiving the heavier ration were slightly inferior as milkers to those receiving the light ration. The report states, "It is not probable that within the limits ordinarily found under practical conditions this factor would exert sufficient influence to be worth consideration."

Effect of Ration upon Maturity.—Animals receiving a heavy ration mature sexually from two to three months earlier than those receiving a light ration. This may be an advantage in that they will come into milk somewhat earlier than the others.

Conclusions.—From the results noted above, we may conclude that heifers should be fed in such a way that they will make good gains, in order that they may obtain their full size. There seems to be no benefit, however, from feeding heifers too heavily. They should be so fed that they will reach their maximum growth as determined by their inheritance. The cows that have made the largest records for both milk and butterfat have invariably been the large animals of the breed. It is true that the stimulation to produce milk may be inherited independently of size; nevertheless, an undersized cow is limited in her capacity to consume and digest feed and cannot compete with a larger cow even though she has inherited to an equal degree the stimulation to give milk. The relation of weight of dairy cows to their production of milk and butterfat is shown in Table LXV.

With these facts in mind, the following feeding recommendations are made for feeding heifers after they are weaned from milk.

TABLE LXV

RELATION OF WEIGHT OF DAIRY COWS TO PRODUCTION OF MILK AND BUTTERFAT WITH PURE-BRED CATTLE *

Average Weight of Cows, lb.	Ayrshire		Guernsey		Holstein		Jersey	
	Milk lb.	Butter-fat lb.	Milk lb.	Butter-fat lb.	Milk lb.	Butter-fat lb.	Milk lb.	Butter-fat lb.
600	....	...	....	...	.....	...	5176	266
700	....	...	5785	276	.....	...	5754	303
800	6235	247	6018	294	7,434	260	6142	320
900	6154	241	6314	309	8,357	288	6422	335
1000	7005	276	6382	315	8,706	298	6670	346
1100	7723	304	6648	325	9,156	311	6857	352
1200	7704	302	6782	334	9,718	328	7162	357
1300	9451	361	6967	328	10,311	347		
1400	....	...	....	...	10,560	355		
1500	....	...	....	...	10,922	369		
1600	....	...	....	...	11,578	392		

* U.S.D.A. Circ. 114.

Feeding the Heifer after Weaning from Milk.—Too often dairymen make the mistake of weaning calves from milk and grain

FIG. 42.—Calves on short pasture need grain and silage.

at the same time and turning them out to pasture and allowing them to graze for themselves. A young heifer six months old will not graze enough even on good pasture to make the gains that she

should. For this reason it is recommended that calves be fed a little grain for the first month or two, or until they become accustomed to the change of feed. Spring calves should also be fed liberally at weaning time on both roughage and grain. After being weaned from milk, fall calves must be carried over two summers, one winter, and usually a part of the second winter, before they freshen. Pasture is by far the most economical means of feeding heifers, and when it is available it should be used to a large extent. After a heifer is eight or ten months of age she will make satisfactory gains on pasture alone, until a few months previous to the time she is due to freshen. The problem of feeding heifers is largely one of winter feeding.

Feeding Heifers during the Winter.—The Missouri Station,[1] after a study of a large number of heifers fed on different rations, made the following recommendations for winter rations:

"When silage and legume hay is on hand, or can be purchased economically, the ration suggested is as follows: corn silage and alfalfa, clover, cow-pea or soy-bean hay at will; and for animals less than ten months old 2 pounds of grain daily in addition. The grain fed may be corn, or a mixture of other grains, if the cost a pound is less. For heifers within three months of calving, 2 to 5 pounds of grain should be fed daily, depending upon conditions. The object is to have them in good flesh at calving time.

"When corn silage is on hand but no legume hay, a satisfactory ration is silage at will for roughage, with some dry feed such as hay or fodder. Two or 3 pounds of concentrates should be fed daily, one-half of which should be a high-protein feed such as gluten feed, linseed meal, or cottonseed meal. The remaining half may be corn, oats, bran, or any other mixture, if cheaper per pound than corn.

"When an abundance of legume hay but no silage is on hand a satisfactory ration is alfalfa, clover, cow-pea or soy-bean hay at will, and 2 pounds of corn daily. Other grains may be substituted with economy if the cost a pound is less than corn. On a ration of legume hay dairy heifers will do fairly well but will not make normal growth. It is believed to be economical, as a rule, to feed a limited amount of grain in addition.

[1] Mo. Exp. Sta. Bul. 158.

"When corn fodder or kaffir fodder, or timothy hay is on hand but no silage or legume hay, it is generally best to purchase legume hay. The suggested ration is legume hay one-half, timothy hay one-half, and corn fodder at will. With this should be fed a grain mixture composed of 1 part of gluten feed, or cottonseed or linseed meal, and 2 parts corn. Other concentrates may be used in place of corn if the cost per pound is less.

"If legume hay cannot be purchased, more grain must be fed for even fair results. Under these conditions the ration suggested is: hay and fodder at will, with 5 pounds daily of a grain mixture

FIG. 43.—Heifers on good pasture make satisfactory growth.

composed of 1 part corn, 1 part bran, 1 part cottonseed meal, linseed meal, or gluten meal."

The Missouri Station found that neither alfalfa nor corn silage was satisfactory for growing heifers when fed alone, but that when they were fed together good results could be expected. The Virginia Experiment Station [1] found that corn silage could be used as the sole roughage, provided that suitable amounts of concentrates were added.

Heifers should be fed a good grain ration, beginning about three months before they are due to freshen, so that they will be in good condition at the time of freshening.

[1] Va. Exp. Sta. Bul. 158.

Age of Breeding

Effects of Early Breeding on Size of Animal.—The age at which heifers should be bred depends upon several factors. In their studies on the subject, the Missouri Station[1] found that, whereas gestation in itself did not affect the rate of growth to any great extent, lactation had a decided influence upon it. Heifers during lactation did not grow nearly as fast as did unbred or pregnant heifers of the same age and breed. As a result, heifers that calved when 20 to 24 months of age did not average so large at maturity as those that calved at a later age. The most decided effect upon the size of the mature dairy cow is produced when the heifer is fed a light ration during the growing period and at the same time bred to calve early. This, no doubt, is one of the main reasons why numerous undersized cows are found in many herds.

Effect of Early Calving on Milk Production.—The following table shows the influence of age at first calving upon the milk production, as found at the Missouri Station:

TABLE LXVI

Influence of Age at First Calving upon Milk Production

Age of Calving	Number of Heifers	First Lactation		Average Three Lactation Periods	
		Milk, lb.	Fat, lb.	Milk, lb.	Fat, lb.
Jerseys					
Under 20 months......	5	2713	147	3,738	207
20 to 24 months......	13	4148	207	4,682	231
24 to 28 months......	20	4675	238	5,076	260
28 to 32 months......	13	5313	266	6,410	328
32 to 36 months......	12	4418	227	5,610	201
Over 36 months......	7	4780	251	5,247	273
Holsteins					
Under 24 months......	6	5506	187	6,873	225
24 to 30 months......	4	8619	266	10,084	307
30 to 36 months......	11	7478	238	8,456	266
Over 36 months......	4	8282	280	11,404	362

[1] Mo. Exp. Sta. Bul. 135 and Mo. Res. Bul. 31.

This table shows that Jerseys should not be bred to freshen before they reach the age of 24 months, and that 26 to 30 months is perhaps the best age at which to have them freshen. After 30 to 32 months they seem to go down in production. With Holsteins, the best production seems to have been obtained with the heifers that were well matured at the time of freshening.

FIG. 44.—Large, thrifty heifers on pasture.

In a study of the dairy herd at the Pennsylvania Station,[1] data were collected on forty grade Guernsey cows that had milked over five lactation periods. From these data the following table was compiled to show the effect of age of calving upon later production:

TABLE LXVII

EFFECT OF AGE OF CALVING ON FAT PRODUCTION

Age of Calving	Average Production of Fat, lb.
18 to 24 months	261
24 to 30 months	268
30 to 36 months	278
36 to 40 months	252

This study seems to indicate that later calving than is usually practiced gives higher production. In consideration of the extra

[1] Pa. Exp. Sta. Rept. 1915–1916.

cost and care, however, it may not be advantageous to keep the heifers to this age before breeding.

A study of the effect of first calving on the official yearly milk and fat production of pure-bred cows of the four main dairy breeds was made at the Missouri Station.[1] It was found that the mean age of calving was as follows: Jersey 27.3 months, Guernsey 28.5 months, Holstein 28.8 months, and Ayrshire 29.8 months. Nothing was gained by delaying the calving date beyond 30 months, and yet 23 to 43 per cent of the heifers in the study calved after that age. It was concluded that the most efficient milk and fat production would be obtained by breeding animals to calve at 20 to 24 months of age, maximum production at about 30 months of age, and within 5 to 10 per cent of the maximum production at 23 to 28 months, depending upon the breed.

Effect of Early Calving on Type.—Eckles found that early calving tended toward a smaller and more refined type of cow than late calving.

Conclusions.—From a consideration of the above, it would seem that the age of first calving should be given some consideration. Calving at too early an age is detrimental to the size and later production of an animal, but not much advantage is to be gained by having the heifers freshen at too late an age. Heifers that have been poorly fed or are small for any reason should not be bred as early as those that are well grown.

Heifers that are normal in size should be bred to freshen at the following ages:

	Months
Jerseys	24–27
Guernseys	26–29
Ayrshires	27–30
Holsteins	27–30

Housing the Heifer

Since the heifer is unproductive, she should be kept as cheaply as possible. The barn in which heifers are kept need not be expensive, but it should be dry and convenient. One of the best types of shelters for heifers is an open shed in which they can be pro-

[1] Mo. Res. Bul. 164.

tected from winds and rains. Many think that such quarters are more healthful than closed barns. Such a shed can be cheaply and easily built.

It is often desirable to have stanchions or some means of tying the heifers while eating; otherwise the larger ones often consume more than their share, while some of the smaller ones go hungry and hence will not make normal growth.

Feeding Standards for Growing Dairy Animals

Table LXVIII shows the requirements of dairy animals of various sizes, for digestible protein, total digestible nutrients, and net energy.

TABLE LXVIII

The Requirements of Digestible Protein, Total Digestible Nutrients and Net Energy for Growing Dairy Animals *

Size of Animal, lb.	Digestible Protein, lb.	Total Digestible Nutrients, lb.	Net Energy, therms
100	0.24–0.40	1.2– 2.0	1.2– 2.0
150	0.41–0.52	2.3– 3.0	2.3– 2.9
200	0.52–0.62	3.3– 4.0	3.2– 3.8
250	0.61–0.71	4.1– 4.8	3.9– 4.5
300	0.67–0.78	4.9– 5.5	4.5– 5.1
400	0.80–0.90	6.1– 6.6	5.5– 5.9
500	0.87–0.98	6.9– 7.7	6.1– 6.8
600	0.94–1.06	7.7– 8.7	6.8– 7.7
700	1.00–1.13	8.4– 9.7	7.3– 8.4
800	1.06–1.20	9.1–10.7	7.9– 9.3
900	1.11–1.27	9.8–11.7	8.5–10.1
1000	1.16–1.33	10.4–12.6	8.9–10.8

* These data are taken by special permission of the Morrison Publishing Company from "Feeds and Feeding," 20th Ed., by F. B. Morrison.

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LECTURE XXII

FEEDING AND CARE OF THE SIRE

LESS is known about the feeding and care of the herd sire than of the dairy cow or the calves and heifers. Probably the main reason for this is that usually there is only one bull on a farm, so that there are very few of them to be cared for and fed as compared to cows and heifers. Furthermore, as they are not productive, there is not as good a means of knowing when they are being properly fed.

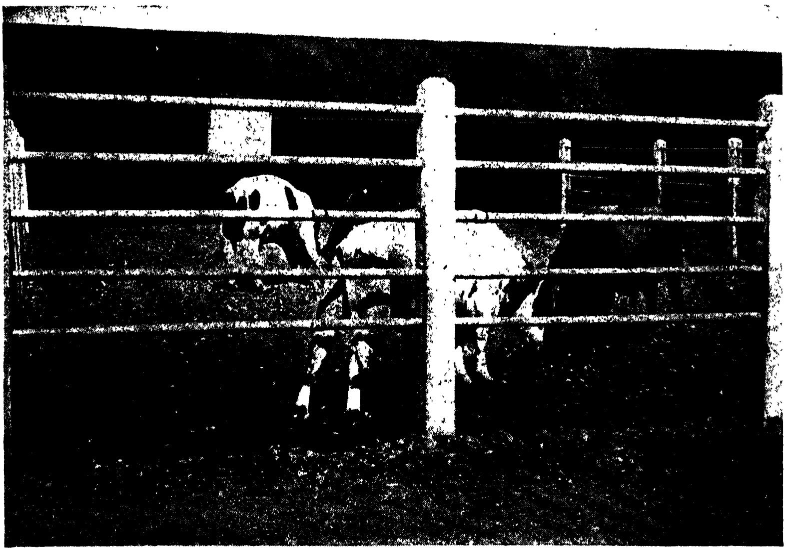

FIG. 45.—A cheap method of exercise for bulls.

Feeding the Bull during the Growing Period.—Since the bull is going to be used at the head of a herd when he is mature, it is very necessary that he be given every possible chance to develop in size to the full extent of his inheritance. A stunted bull that never reaches its maximum size may be just as good a breeder as a well-grown one but there is no way to tell that the smallness is not due to inheritance, and the animal is looked upon with disfavor by

those who do not know his history. For this reason the bull should be well fed from birth. Table LXIX shows the normal growth of

TABLE LXIX

NORMAL GROWTH IN WEIGHT AND HEIGHT OF DAIRY BULLS

Age Month	Ayrshire		Holstein		Jersey		Guernsey	
	Weight, lb.	Height at Withers, in.	Weight, lb.	Height at Withers, in.	Weight, lb.	Height at Withers, in.	Weight, lb.	Height at Withers, in.
Birth	81	27.5	94	29.4	60	26.2	71	27.7
1	101	28.4	125	31.2	78	27.9	87	29.3
2	133	29.7	164	33.2	104	29.7	113	30.6
3	173	32.7	214	34.8	141	31.5	147	32.4
4	217	34.5	269	36.4	184	33.6	190	34.2
5	267	36.1	336	38.8	233	35.5	237	36.1
6	321	37.9	399	40.5	282	37.2	291	37.8
7	378	39.4	456	41.9	326	38.4	345	39.2
8	433	40.2	514	43.1	370	39.5	401	40.3
9	488	41.5	563	44.2	410	40.4	443	41.5
10	532	42.2	620	45.1	452	41.4	494	42.5
11	558	42.8	683	46.4	497	42.7	547	43.3
12	599	43.3	741	47.5	531	43.0	609	44.5
18	751	46.4	1176	52.2	745	47.5		
24	990	48.1	1438	55.9	969	50.3		

bulls of the various breeds, according to the Missouri Experiment Station.[1]

For the first six months of his life, the young bull should receive the same care and feed as a well-cared-for heifer. It is best to feed him on skimmilk, if this is at all possible, rather than to try to use substitutes. If skimmilk is not available, whole milk should be used for a longer time in order to give him a good start. Since he is to head the herd, the item of cost should not be considered as much as in the raising of a heifer. He should be fed in such a way that he will always be thrifty and growthy.

Skimmilk, when available, is often fed to the young bull for eight or ten months. This has been found to be a good practice,

[1] Mo. Exp. Sta. Bul. 336.

as skimmilk is one of the best feeds to provide ash for bone growth. Most bulls, however, are weaned from milk at six months of age. At this time they should be fed a good grain ration containing from 12 to 15 per cent protein and practically all the good legume hay that they desire. Almost any combination of grain is satisfactory, although if non-legume hays are fed, a ration higher in protein is necessary. In that case a ration similar to 2 below will be recommended. Grain mixtures which have been recommended for feeding at this time are as follows:

Ration 1	Ration 2
5 parts wheat bran	2 parts corn or barley
4 parts ground oats	3 parts oats
1 part linseed meal	3 parts bran
	2 parts linseed meal

Most feeders use the same grain mixture which is fed to the dairy heifers. The young bull should be fed from 4 to 8 pounds of grain daily, depending upon his size and the amount of service he is allowed. The amount of legume hay which a bull will consume depends upon his size; a mature bull will eat as much as 10 to 20 pounds daily.

There is a belief among feeders that silage fed to bulls reduces their potency. Although there are no experimental data to warrant this belief, many breeders feel that such impairment has occurred. Others, however, feed silage in large quantities and do not seem to get any undesirable results as far as breeding qualities are concerned. As much as 10 to 15 pounds of silage has been fed without any undesirable effects. Large amounts of silage or other bulky feeds may have a tendency to distend the paunch so that the bull may become too heavy on his feet. This feeling against silage does not seem to be held in regard to such other succulents as roots, green forage crops, and grass.

Feeding the Service Bull.—A bull in service should not be fat but should be fed so that he is in good breeding condition. It is a common belief that a fat bull lacks stamina, and that he may even become impotent from too much fat. On the other hand, a bull should not be allowed to become too thin. If the conditions on a farm are such that breeding is limited to one season, the bull should

be so fed that he is gaining in weight during this period. On most farms, however, it is necessary to have cows bred to freshen the year round, a fact which naturally causes the breeding to extend over a longer period of time. Bulls in such herds must be fed in much the same manner at all seasons of the year.

FIG. 46.—Bull exercising on wire cable.

Some dairymen feed the bull the same grain mixture that they feed the herd, on the assumption that to be in good breeding condition he should receive a reasonable amount of protein. A common grain ration for the mature bull after complete growth is as follows:

3 parts corn meal
3 parts ground oats
3 parts wheat bran
1 part linseed meal

This should be fed with legume hay. If non-legume hays are fed, it is necessary to have more protein in the grain mixture, especially during the heavy breeding season. The importance of good-quality legume hay cannot be overemphasized. It is not only a good feed containing abundance of protein, minerals, and vitamins, but its smaller bulk tends to keep the paunch from becoming greatly ex-

tended. The practice of giving only the low-grade roughages to bulls is not to be recommended. Bulls are not usually turned on pasture under best management. It is better if green food is brought to his pen, as most pastures are not well enough fenced to hold a mature bull. It is never wise to allow the bull to run with the herd; not only is it dangerous, but also cows will be bred unknown to the owner. Green feed and sunlight are, however, very beneficial to the breeding bull.

Teaching the Bull to Lead.—When the bull calf is five or six months of age he should be separated from the heifer calves, because at that age he becomes sexually mature and may breed some of the young heifers if allowed to run with them. At that age, or even before, he should be taught to lead so that he may be more easily handled when older. It is best to lead him a little every day, but if this is not possible he should be led at least once a week.

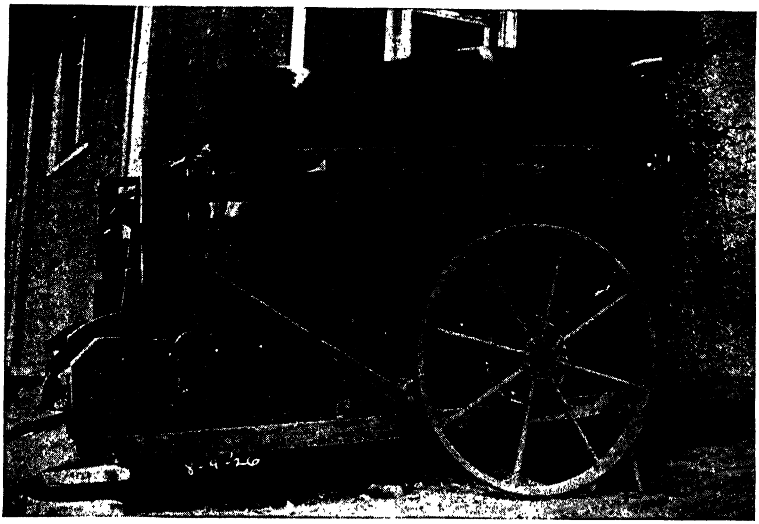

FIG. 47.—Bull being exercised in tread mill.

Ringing the Bull.—When eight or ten months of age a bull should have a ring put in his nose. The ring at this time should be of light weight and about 1½ inches in diameter. It should be of some non-rusting material, such as copper, brass, or cannon metal

When the bull is about eighteen months or two years old this ring should be replaced with a larger one, and when he is three or four years old this should be replaced with a 3-inch ring.

To ring the bull, it is advisable to have him well fastened in a stanchion or stocks. The opening through the cartilage may easily be made by means of a bull nose punch. The ring is then put in and fastened securely by a screw. Care should be taken to change the ring before it becomes too badly worn, because a weak ring often causes trouble.

Staffs.—After the bull has a ring in his nose he should be trained to lead with a staff. One should never take chances with a large bull because he may become vicious at any time. Many makes of staffs are on the market, some of which are fitted with special devices designed particularly to handle vicious bulls. The staff should always be used on all bulls, as it is usually the "gentle" bull that causes trouble. The owner of a vicious bull is generally prepared against him.

Dehorning.—If the bull is to be kept in a herd where showing at fairs is not practiced, it is advisable to prevent the growth of the horns by the use of caustic, as described previously. Many seem to prefer to allow the horns to grow until the bull is about two years of age, and then take them off. They think that the bull once having learned to use his horns, misses them and becomes much more tractable than he would be otherwise. Since bulls are always more or less dangerous, it is recommended that their horns be removed, except in herds of highly developed pure-breds. The dehorning of a mature bull is quite an undertaking unless one is equipped for it. The removing of the horns does not in any way affect the potency of the bull.

Service.—It is the general opinion among breeders that the young bull should not be allowed to serve an animal until he is at least ten months of age, and then only if he is a vigorous, well-grown animal. The amount of service should be limited, until he is about eighteen months of age, to not more than two services a week. As he grows older, however, he can be given more liberal service. Mature bulls may be used on as many as 200 cows per year, if they are evenly distributed throughout the year. However, on most farms the breeding cannot be evenly distributed; therefore,

it is usual to keep one bull to each 50 or 60 cows. Young bulls should not be used too frequently as this may be responsible for a decline in their vigor and potency.

Bulls should not be allowed to run with the herd during the breeding season. One of the reasons for this is that a bull running in pasture is in contact with a cow in heat, causing dissipation on his part, a condition that brings on impotency much earlier than it would otherwise occur.

It is a custom in many sections of the country for a cow to receive two services from the bull. This is a needless waste of the energy of the bull. Nature is lavish in anticipation of reproduction, and one service properly conducted is sufficient to impregnate many

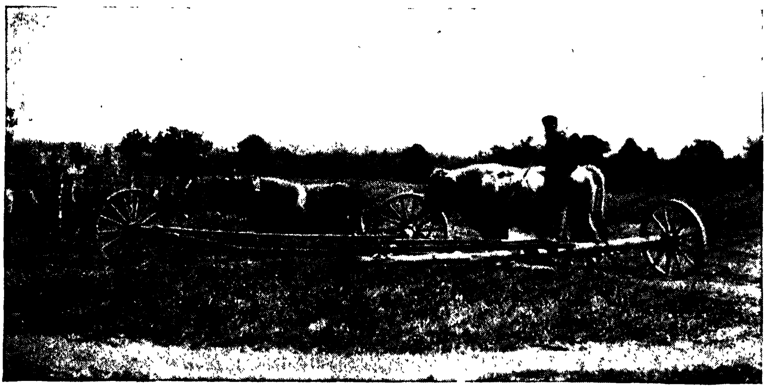

FIG. 48.—An exercise, specially constructed for bulls.

animals. Careful service will do much to preserve a bull's breeding qualities until old age. Usually a bull when he reaches the age of eight or ten years becomes slow when breeding and often becomes uncertain.

Exercise.—The importance of exercise for the dairy bull has not been fully realized in the past. Many dairymen who keep their bulls away from the herd retain them in a small paddock where they have little exercise from the time they are calves until they reach maturity. Such treatment will usually lead sooner or later to impotency of the bull. To avoid this, some form of exercise must be provided. Many dairymen keep their bulls in pens which open into a common paddock where they are turned for their exercise.

The older bulls are first dehorned, and the butting which they practice on one another gives them the needed exercise.

Others exercise the bulls in tread mills with which they separate their milk or pump their water. Still others arrange a long sweep to which the bulls are fastened. Usually one of the animals is driven and this forces the others around with him. Other systems have been used, but the main thing to keep in mind is that the bull should be given an ample amount of exercise. A bull kept in a paddock by himself, without being forced to take exercise, will not usually obtain sufficient to keep him in good shape.

FIG. 49.—A safe and desirable bull fence.

Housing the Bull.—Too often the bull is kept in a dark, dirty stall and kept tied most of the time. Since the bull has so much influence on the success of the herd, he should be given comfortable quarters. Many dairymen keep the bull in a box stall in the same barn with the milking herd, but most of them seem to prefer to keep him in a separate barn away from all other dairy animals. The stall should be about 12 feet square. It should open into a strongly fenced paddock into which the animals are turned daily. The stalls should be strongly built. Ordinary cow stalls are strong

enough for most bulls. The pen should have a stanchion into which the bull can be tied during cleaning time.

The bull pens need not be tightly made. A good roof and a wall to keep the wind and rain off the animal are all that is necessary. A certain amount of exposure will not harm the bull, provided he has a dry, well-bedded stall into which to go during cold, windy, or rainy weather. Of course, if the bulls are to be kept looking their best at all times they should be kept in except on fine days.

Handling Vicious Bulls.—It often occurs that a valuable bull becomes vicious at the age of about five years, just about the time that his first daughters are in milk. Bulls should always be handled kindly and should never be teased. The attendant that handles the bull should never show any fear of the animal. He should handle the bull firmly and let him know that he is his master. A bull always seems to know when anyone is afraid of him and will make trouble for one who shows fear.

Great care should be taken to make the stalls and fences surrounding the paddock strong and reliable so that the bull will have no opportunity to realize his own power.

He should always be led with a staff, and if he is very vicious two men should be used to lead him, one on each side. Each person may use a staff attached to a separate ring in the nose, or one may lead him with a strong staff while the other uses a rope or strap fastened into the second ring. Often vicious bulls are kept in such a way that they need be handled but very little. A breeding pen can be built in connection with the bull's pen in such a way that, with a series of gates, the cows can be bred without handling the bull. This is a very satisfactory way to manage bulls, and is recommended in the handling of all bulls. The details of a safety bull pen are shown in Fig. 50.

Impotency.—Many bulls as they become older become less certain as breeders and often lose their potency entirely. This may be due to several factors. The most common are improper feeding, insufficient exercise, and excessive breeding. Very little is known concerning this problem. If more were known about the feeding of breeding bulls, this trouble would probably be greatly lessened. The exercising of the bull is also being recognized as a very important

factor in helping to retain his potency. Bulls may be made impotent by improper feeding and then made potent again by proper feeding and exercise. Care should also be taken that the bulls are not given excessive service, especially when young.

Often very valuable bulls become useless at an early age just when their usefulness should be beginning. Greater attention to feeding and exercise would greatly lessen this trouble.

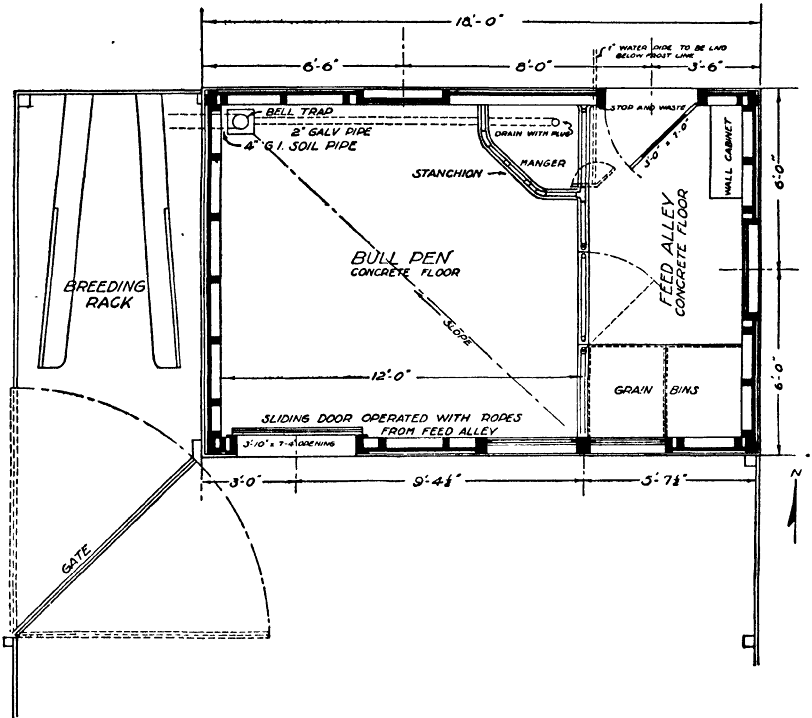

FIG. 50.—Plans showing the details of a safety bull pen.

Disposal of the Sire.—When a sire has been used in a herd, he should not be disposed of by sale, slaughter, or otherwise, except perhaps to be loaned out to another breeder, until his daughters have come into milk. Many bulls are sold before their real value has been discovered. The first heifers do not come into milk until the bull is four or five years old. Usually the bull has been disposed of before that age is reached, and so, if his daughters prove to be exceptional milkers, it is then too late to get him back. If

such a bull has been retained he should not be sold as long as he keeps his breeding power. After he has passed his service days in one herd he should be transferred to another. Many instances are on record in which bulls have been transferred from one herd to another and in each herd have improved the records of the daughters over those of the dams. A bull properly handled should easily breed from nine to ten years, and many will breed much longer than this, even to sixteen or eighteen years of age. Several methods have been used to retain the bulls until the worth of their daughters is known. Some large breeders put bulls out with other breeders, with an agreement that they may be secured again when needed. Others sell bulls with the option of buying them back again at a certain price if desired. Others retain them in their own herd with limited use.

If the bull proves to be a poor breeder or if he becomes impotent for any reason, he should immediately be disposed of to the butcher.

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LECTURE XXIII

THE PRINCIPLES OF DAIRY-CATTLE BREEDING

ALTHOUGH dairy animals have been used since the dawn of history, the study of their breeding is of recent development. All breeding up to the time of Robert Bakewell of Deshley Hall, Leicestershire, England, in the middle of the eighteenth century, was without scientific foundation. The early herdsman may have used selection to a very limited extent, but if so they had no knowledge of the reason for so doing. It was Bakewell who began to improve animals by a method founded upon the principle that "like produces like." By careful selection and by mating animals resembling each other closely in conformation, he was able to fix the type that he desired. By this method it has been possible to establish breeds of livestock which have done more to bring about better animals than any other one factor.

It is true that the ancestry of many of our dairy breeds may be traced back for several hundreds or even thousands of years. Caesar found in Friesland the ancestors of our present Holsteins, even then developed into a very good type of dairy animal. The Brown Swiss and the Simmenthaler have lived for hundreds of years in the mountains of Switzerland. However, up to the time of Bakewell, the introduction of new types into a country was brought about by conquest or by migration, and these were the chief factors in the development of distinct breeds.

Today all cattle breeding can be classed under the two heads of breed improvement and herd improvement. The country as a whole, of course, is greatly interested in dairy-cattle breed improvement, which is a factor of great importance. Each individual dairy farmer, however, is chiefly interested in herd improvement. If he is able to improve his herd so that he gets a greater return for his labor, it means much to his own welfare. Whatever is for permanent herd

improvement must in the end react for permanent breed improvement. In fact, all the important breed improvements during the past years have come about largely through the great strides made by some of the master breeders in their own herd improvement.

The early breeders did not fully understand the reason for selection and close breeding, but the breeder of today has an explanation of the good results of these practices, and an understanding of the factors underlying breeding helps him in his breeding operations.

Carriers of Heredity

The cell, as previously stated, is the unit of life. The body is made up of cells grouped together in a compact mass. There are two kinds of cells in the animal body—the body cells and the germ cells. The body cells, which constitute the bulk of the individual, last but one generation and then die. The germ cells, however, go on from generation to generation. They are specialized for reproduction and contain the hereditary material which determines the identity of each individual and which is known as germ plasm. This is the part of the living substance which passes down the line of descent from one generation to another.

Each cell contains within its walls a small body known as the nucleus, containing a number of microscopic bodies known as chromosomes. These are found in pairs and in a definite number for each species of plant or animal. The dairy cow, for example, has 38 chromosomes, and the human has 48. The chromosomes are considered the bearers of the elements that determine the inheritance of any animal. These elements, or factors, as they are called, which determine the inheritance, appear to be strung along the chromosome in a linear arrangement. Each of the factors is distinct and is transmitted from one generation to another without undergoing any change or becoming contaminated by association with others. They do not mix like milk and water, but rather like black and white marbles. Although these factors are distinct units in themselves, it often requires many of them to bring out a character. A character, then, is the result of the interaction of many factors plus environment. Milk production and butterfat percentage are

probably dependent on the cumulative effect of a number of such factors.

The Cell in Reproduction

The mature germ cell of the female is called the ovum, or egg, and that of the male is called the sperm. In the formation of mature germ cells the cell divides, and each sperm or egg contains only one-half the normal number of chromosomes.

"About the period of heat of the cow, one or more of the clear vesicles which can be seen in the ovary enlarges and ruptures. There is expelled a tiny colorless ovum or egg which can only be seen with difficulty by the naked eye. This ovum is received within the funnel-like membrane which normally surrounds the ovary, and then passes to the apex of this funnel and then into the narrow duct leading to the horn of the uterus. It is while in this duct that it comes in contact with a large number of male germ cells. A single sperm gains access to the ovum and fusion of the two results. This constitutes the act of fertilization, and the life of a new individual commences at once.

"The ovum carries the complete contribution of hereditary factors which are supplied by the mother while the sperm carries the complete paternal set. The fertilized ovum now commences to divide, and a process of rapid multiplication sets in." [1]

This leads to the development of a new individual with a new set of characteristics contributed equally by the male and the female.

Mendel's Law

Inheritance is fixed at the time of the fertilization of the egg. It cannot be changed. An individual may fail because of environmental conditions to reach the full development of the inherited qualities with which he is endowed, but he can never exceed his inherited possibilities.

The laws of heredity were first discovered by Johann Gregor Mendel, an Austrian monk, who published the results of his work in 1866 after eight years of careful experimenting. His paper was not appreciated for several years, but in 1900 it was brought to

[1] Recent Developments in Cattle Breeding, Finlay.

light, and since that time it has been the general guide for students of genetics. Mendel experimented with peas and, by studying the inheritance of simple characters, such as size of pea or color of flower, was able to formulate the principles of inheritance, very much as they are understood at the present time. He found that when tall and dwarf varieties were crossed all the progeny of the first generation were tall; hence, tallness is said to be "dominant" over dwarfness, and dwarfness to be "recessive." However, when these hybrid peas of the first generation were planted they produced a mixed progeny, three-fourths of which were tall and one-fourth

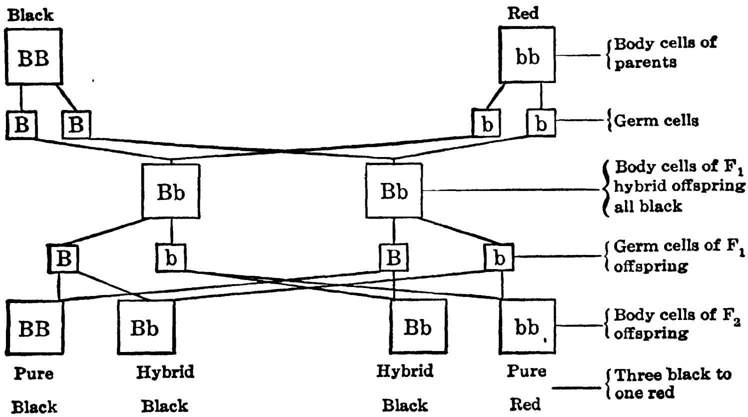

FIG. 51.—Illustration of Mendel's Law. When a pure black animal is mated with a pure red animal, the offspring will be black but will carry factors for red. If these are mated, the resulting offspring will be three blacks to one red.

dwarf. By planting the dwarf peas it was found that they invariably bred true to dwarfness; but the tall variety did not behave in this manner. Careful study disclosed that one-third of the tall peas bred true to tallness, whereas two-thirds, though tall themselves, bred both tall and dwarf in the proportion of three to one, like the first generation.

In the same way the factors in the animal body segregate at the time of mating. For example, if a red cow were bred to a black bull, all the first-generation offspring would be black; hence, black is said to be dominant over red. In the second generation, the offspring would split up in the proportion of three blacks to one red.

The red would breed true to red when mated with red, and one-third of the blacks would breed true to black; but the others would give three blacks to one red, like the first generation. This is illustrated in Fig. 51.

Figure 51 also illustrates how an animal may be black in color but may carry factors for red and, when mated with another animal of the same factoral constitution, may give a red calf. Such cases, though not common in the United States, frequently occur in the Holstein breed. Recessive factors may be carried for several generations without external manifestation, but when they recombine with other factors of the same kind the character will reappear. An animal that is pure for a pair of factors, as, for example, the animal containing *BB* in the preceding illustration, is described as being homozygous, and an animal that has both members of a pair of factors is described as being heterozygous, as, for example, the animal containing *Bb* in the foregoing illustration. The essential feature of Mendel's law, as stated briefly by Walter, is as follows: "Hereditary characters are usually independent units which segregate out upon crossing, regardless of temporary dominance."[1]

The foregoing example of Mendelian inheritance is for single unit characters. Such inheritance is comparatively simple; but when the two organisms that are crossed differ from each other with respect to two or more different unit characters, the problem becomes more complicated. Crosses of the latter type will not be considered in this lecture.

Inheritance of Milk Production and Butterfat Percentage

In the study of dairy cattle, milk production and butterfat percentage are the characters that are the most important economically. The study of genetics, however, has not as yet helped greatly with the problem presented by these two characters. The evidence for the inheritance of milk production and fat percentage indicates that, like most other characters in animals, they are dependent on a number of factors for their development, and that the two characters are inherited independently of each other. The problem of breeding

[1] Genetics, Walter.

for high milk production and high percentage of fat is one of breeding animals which are homozygous for most of the factors controlling these characters. If a dairyman has at the head of his herd a sire that is heterozygous for high production, and this sire is mated with cows which, although good producers themselves, carry factors for low milk production, some of the offspring will be poor producers, some may be good producers but may be carriers of factors for low production, while a few may be good producers and breed true. The problem, then, is to secure a sire that is homozygous for high milk production. Such a sire will produce high-producing cows even though the cows to which he is bred are low producers. The only sure indication of such a sire is the breeding test, by which a sufficient number of his daughters are observed to see whether they inherit the characters desired. If all the daughters inherit the desired character, the sire may be considered homozygous for high production. If, however, he has some good daughters and some poor ones, he may be considered heterozygous for high production. It can be seen from this that a cow may be a good milk producer herself but yet carry factors for low production. This shows how a person may be led astray by choosing animals out of cows with high official records. A high official record does not in itself insure that the offspring of the individual possessing it will be able to make a high record or that their offspring will produce well. The only animals that can consistently produce offspring with high milk production are those that carry many of the factors for high milk production in a homozygous condition.

The same generalizations can be made about butterfat percentage as have been made about milk production. Wilson [1] found that capacities to produce milk and fat are inherited entirely independently. He believes that there is no reason why it should not be possible to breed cattle giving a large quantity of milk as well as a high quality. It has also been found that high milk production is dominant over low milk production, but low fat percentage is dominant over high fat percentage.

All breeding results can be explained by means of Mendel's law, although many believe in the inheritance of acquired characters.

[1] The Principles of Stock Breeding, Wilson.

DETERMINATION OF SEX

Many theories have been advanced concerning the method of controlling the sex of an individual before birth. Most of these have no scientific background and have not stood the test of experimentation. Wodsedalek,[1] however, has after careful research offered an explanation of the determination of sex in cattle, which has generally been accepted. He found that the male has 37 chromosomes. Of these, 1 is a sex chromosome and the other 36 are the ordinary chromosomes, called autosomes. The female, on the other hand, has 38 chromosomes, of which 36 are ordinary and the other 2 are sex chromosomes. During the reduction the male forms two types of sperms, one of which carries a sex chromosome while the other does not. The female forms only one type of egg. At fertilization, when the sperm unites with the egg, one-half of the resulting offspring will be males, that is, will carry 37 chromosomes, while the other half will be females and will carry 38 chromosomes as shown in Fig. 52.

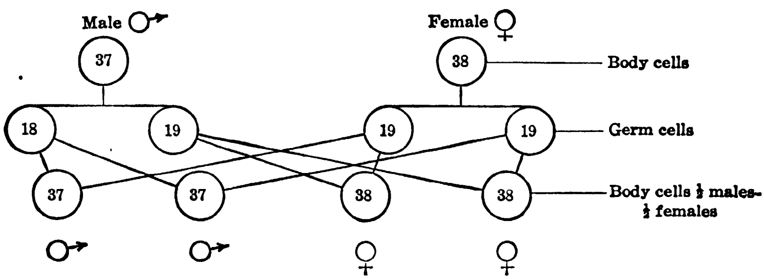

FIG. 52.—Illustration of sex determination in cattle.

There is, therefore, no way of controlling sex. It is simply a matter of chance whether the female germ cell will unite with a male germ cell containing 17 chromosomes or with one containing 18 chromosomes. It often occurs that a breeder obtains a preponderance of one sex or the other in a given year, but this is entirely the result of chance. If a sufficient number of animals are considered, the proportion of male and female will usually be about one to one.

[1] Biol. Bul. 38 (1920).

Relative Importance of Sire and Dam

It can be seen from Fig. 52 that all the daughters receive an equal number of chromosomes from each parent. The sons, however, receive 19 chromosomes from the dam and only 18 from the sire. It is quite probable that a bull receives a slightly greater inheritance from his dam than from his sire. It has not been demonstrated, however, that any of the factors which control milk production or butterfat percentage are carried on the sex chromosome. Gowen,[1] after extensive studies with the Holstein-Friesian cows in the advanced registry, concluded that the sire and the dam are equally responsible for the milk yield and butterfat percentage of the daughter. However, this need not mean that one parent may not give more characters to the offspring than the other. The animal that carries the greatest number of dominant factors may stamp his or her individuality upon the offspring to the exclusion of the less dominant parent. However, it must be borne in mind that the offspring of such a mating will be heterozygous, and will carry factors of both parents which may be passed on to its offspring. An animal that will pass on its characters to its offspring regardless of how it is mated is called a *prepotent animal.* Such an animal carries the factors for the expression of its characters, which may be undesirable or desirable, in a homozygous state. As noted before, milk production or butterfat percentage is the result of the interaction of several different factors. It is therefore very unusual for an animal to carry all the factors for the expression of these characters. When this occurs it can be seen that the individual is a very valuable one. The only method of recognizing such an individual is the testing out of a sufficient number of its offspring.

Other Characters

Although milk production and butterfat percentage are the characters usually considered in the breeding of dairy cattle, others should be considered as they have an economic value. The most important of these are type, constitution, longevity, and fertility. These characters are probably inherited by the Mendelian law in

[1] Milk Secretion, Gowen.

the same manner as the others. Type is particularly important to the man who is in the show business. Every breeder, however, should give it a certain amount of consideration, or the type of his animals will become such that he will have difficulty in disposing of them.

Many families of dairy animals are notably shy breeders. This character is a very important one. No matter what factors for milk production an animal may inherit, she will be a great economic loss if, because of failure to breed, she is not able to pass on these factors regularly to her offspring. Many kinds of sterility, however, are due to disease.

Other animals may inherit the capacity for high milk production but may not inherit the constitution and longevity to enable them to stand up under the production of which they are capable. All these factors should be considered in the breeding of animals.

The Freemartin

At least one kind of sterility in cattle is not due to disease or inheritance. When a female calf is born as a twin to a male calf, a sterile female, known as a freemartin, usually results. The freemartin is a female in which the reproductive organs have failed to develop properly. In consequence such an animal is not only sterile but also develops certain characteristics of the male. The male of such a union would breed normally.

Lillie,[1] after extensive investigation, found that this condition is due to the fact that the choria, or membranes, which surround the individuals are united in such a way that the circulatory systems of the two are joined and the blood of one individual circulates through the body of the other. The blood of the female does not interfere in any way with the normal development of the male, but the blood of the male circulating in the female seems to inhibit her full sexual development. This is thought to be due to a hormone which is secreted by the testes of the male and carried through the blood, inhibiting the full development of the female sexual organs. Such females will not breed. Occasionally a female born with a male will breed. This is due to the fact that the choria of the two

[1] Sci. 43 : 611.

animals remain distinct so that each has its own circulatory system. Then the female is not a freemartin. Males born with males or females born with females should breed normally.

Fixation of Hereditary Qualities

It is necessary, then, as we have seen, to have animals that are prepotent—animals that will pass their characters on to their offspring. It is known that all animals vary greatly in their characters; but if one is to breed prepotent animals one must breed individuals that do not have great variation from one generation to another. Variations in dairy cattle are of two general types: first, those due to environmental conditions; and second, those due to germinal recombinations. Environmental variations may affect the individual, but they in no way affect the germ plasm and so are not inherited. Most hereditary variations are due simply to recombination of the factors already present in the parents. These are the variations which the careful breeder will attempt to eliminate.

Selection.—Consistent selection, directed toward a desired type, is sometimes all that is necessary to fix a character. It is necessary in breeding operations, however, to have clearly in mind the desired type as the ideal toward which one must work. In the dairy field, it is important to select animals of the desired type and with high milk production back of them. In herds of very high milk production, it is necessary to select only those males that have been proved to carry the factors for high milk production. Otherwise, an unfortunate selection may upset the progress made. Selection alone, therefore, is not certain to result in steady progress. Even at its best, it is a slow method of effecting fixation of desirable hereditary qualities.

Inbreeding.—Inbreeding may be defined as the breeding of very close relatives, as son to dam, sire to daughters, or brother to sister. It is one method of fixing characters, whether good, bad, or indifferent. Two related parents have a more nearly uniform character in their hereditary material than two unrelated parents. The offspring, therefore, should have more of the characteristics of the parents. In other words, if the characters become homozygous and if they are desirable characters, the resulting animal will be a de-

sirable one. However, if they carry factors that are not so desirable, the resulting animal will become homozygous for such factors also. It is very seldom that an animal has all the desirable characters; therefore, when inbreeding is practiced, some undesirable characters may be developed along with the desirable ones. For example, in dairy cattle, the character for high milk production might become homozygous, and at the same time the character for low fertility or for poor constitution might become homozygous; thus, while a desirable character is being fixed, others that rob it of its usefulness may also be fixed. Inbreeding should not be used, therefore, without rigid selection. Success has followed the inbreeding of smaller animals, such as the drosophila fly, the rat, and the guinea pig, when careful selection has been practiced. Inbreeding of dairy cattle should be practiced only by the most skillful breeders.

Line Breeding.—Line breeding is the breeding of animals more or less closely related, but not so closely as those mated in inbreeding. Line breeding is the most popular form of breeding practiced today. It is a moderate form of inbreeding and possesses its advantages and disadvantages to a lesser degree. It promotes uniformity in the characteristics but brings in more hereditary influence from unrelated animals, hence homozygosity is not reached so quickly as with inbreeding. But while desirable characteristics are not developed so quickly, neither do the harmful ones appear so readily. Line breeding is a slower method than inbreeding for the fixation of hereditary qualities, but one which most breeders prefer as it decreases the dangers associated with inbreeding.

Outcrossing.—Outcrossing is the system of mating in which animals of different strains, or blood lines, are mated. It is quite evident that the animals resulting from such a mating will be heterozygous for every single factor in which the two strains differ completely. If, however, the same general type has been fixed in two unrelated families, there is no reason why the crossing of these two families should result in offspring having a great variation in type. Of course, where families of distinctly different types are mated, a variation in type in the offspring is to be expected.

"If sire *A* is homozygous for dominant factors determining high production and his heterozygous daughters are bred back to him, half of his inbred offspring will be homozygous and half hetero-

zygous. What will result if *A*'s daughters are mated to sire *B* who is also homozygous for dominant factors determining high producing capacity but is not related to sire *A*? If sire *B* has the same combination of factors that enable him to sire high-producing daughters as has sire *A* there is no reason why the results should not be the same as when sire *A*'s daughters are mated back to him." [1]

Although it is not known definitely that the same combination of factors enables each of them to get the same desirable results, yet the indications from studies of advanced-registry records are that the factors controlling high producing capacity are alike in most prepotent sires of the same breed. The advantage of inbreeding or line breeding in the fixation of desirable hereditary qualities, such as milk production, is that the characters of the sires or dams definitely known to be great breeders can be concentrated. Ancestors that might be poor are eliminated to the extent of the duplication. In crossbreeding, the hereditary qualities of more animals must be known than in inbreeding; but if two animals are known to have the combination of factors for high production, good results may be expected from crossbreeding. If, however, the hereditary qualities of the animals are not known, it may be dangerous to use this method.

Grading.—With grade herds the methods of breeding discussed above are of little importance, and grading is used extensively. This term is used to describe the system of breeding by which a stock is led, generation after generation, a step nearer to a pure-bred type. The start is usually made with ordinary stock of no particular breeding; if a pure-bred sire is used in such a herd the first generation will be half-breeds. With the continued use of a pure-bred sire the second generation will be three-quarters pure-bred, and the third generation seven-eighths pure-bred, and the fourth fifteen-sixteenths pure-bred. These would have the same types and characters as the pure-bred animals and could not be distinguished from them.

As a general policy, grading is by far the most important system in this country. Only a very small percentage of our dairy animals are pure-bred, most of the herds being grade. The grading up of herds is a very important factor in the increasing of production in

[1] Proc. World's Dairy Congress 2: 1381.

this country. Of course, pure-breds are necessary to furnish the desired seed in the grade herds.

Pedigree.—A pedigree is a record of the ancestors of an animal. The modern pedigree contains the record of the actual production of the ancestry. The pedigree, however, should not be given such prominence that defects of individuality are overlooked. Galton, an English investigator, after studying many human pedigrees, came to the conclusion that any individual is made up of 50 per cent of the immediate parents, 25 per cent of the grandparents, 12½ per cent of the great-grandparents, 6¼ per cent of the great-great-grandparents, and so on. Galton's law, of course, is supposed to apply only to the average, as individuals vary from this because of different combinations of hereditary factors. This illustrates, however, the undesirability of paying much attention to individuals too far back in the pedigree. For example, in the third generation there would be eight ancestors, and since only 12½ per cent of the hereditary influence comes from this generation each individual would count for only 1.56 per cent of the hereditary make-up. The parents, sisters, half-sisters, grandparents, and, to some extent, cousins are the important relatives upon which to base an estimate of the production worth of animals.

Care should be taken in interpreting pedigrees by those not accustomed to them. Since pedigrees are used extensively in the selling of animals, many abuses have arisen in the method of preparing them, especially in regard to the records of production. In most cases the truth is told but the statements are made in such a way that unless one is on the watch one may be fooled into thinking that an animal has a better pedigree than it really has. An illustration of a good pedigree is given on page 318.

Fallacies in Breeding

Telegony.—Many breeders believed, in the past, before some of the recently discovered laws were known, that late offspring were likely to be affected to some extent by previous impregnations of the mother. According to this belief, a pure-bred Holstein cow bred to a Holstein bull after dropping the offspring of a Jersey bull would not drop a pure-bred Holstein calf. Fortunately, this belief

A GOOD PEDIGREE

VARSITY PIEBE LA VERTEX 302952
(19–19–14–0–0)
6 nearest dams with 365-day records, some at immature ages, average:
20424 lb. milk
705.6 lb. fat
882.0 lb. butter
Sire of La Vertex Quantity of U. Neb.
2 yrs. 20454 lb. milk; 722.7 lb. fat; 903 lb. butter
N. P. Ragapple Bleske Piebe
2 yrs. 19568 lb. milk; 646.9 lb. fat; 808.6 lb. butter
N. P. Topsy King Piebe
2 yrs. 17800 lb. milk; 618.5 lb. fat; 773.1 lb. butter

King Piebe Pontiac Segis 174303....
(17–15–17–4–7)
Sire of Beauty Girl Gerben ReBecky
1 yr. @ 4 yrs. 21869.4 lb. milk; 790.44 lb. fat; 985.55 lb. butter
7 days @ 4 yrs. 683.5 lb. milk; 34.33 lb. butter
Varsity Piebe Quintelle
1 yr. @ 3 yrs. 18840.1 lb. milk; 683.35 lb. fat; 854.18 lb. butter
Varsity Piebe Kismet
1 yr. @ 2 yrs. 17914.6 lb. milk; 592.06 lb. fat; 740.07 lb. butter
7 days @ 3 yrs. 612.7 lb. milk; 25.01 lb. fat; 31.26 lb. butter

La Verna Lincoln 227365..........
(3–1–1)
1 yr. 29555.5 lb. milk; 1048.46 lb. fat; 1310.60 lb. butter
7 days 729.0 lb. milk; 27.52 lb. fat; 34.41 lb. butter
Dam of Varsity Derby La Vinnie
1 yr. 22421.0 lb. milk; 805.97 lb. fat; 1007.46 lb. butter

Piebe Laura Ollie Homestead King 110474....................
(59–55–48–27–26)
Sire of: 3 over 800 lb. fat or 1000 lb. butter; 5 over 700 lb. fat; 13 over 600 lb. fat.
May Walker Ollie Homestead
1 yr. 31610 lb. milk; 1218.59 lb. fat; 1523.23 lb. butter
Watson Segis Pontiac Homestead
1 yr. 25310 lb. milk; 927.85 lb. fat; 1159.81 lb. butter

Beauty Girl Pontiac Segis 229260...
1 yr. @ 3 yrs. 24924.7 lb. milk; 890.33 lb. fat; 1112.91 lb. butter
7 days @ 3 yrs. 713.5 lb. milk; 29.72 lb. fat; 37.15 lb. butter

Prince Ormsby Mercedes DeKol 47008....................
(7–4–10–8)
Sire of La Verna Lincoln
1 yr. 29555.5 lb milk; 1048.46 lb. fat; 1310.60 lb. butter
Allie Lincoln
1 yr. 22159.6 lb. milk; 846.22 lb. fat; 1057.77 lb. butter
7 daughters average 24 lb. butter in 7 days

La May 122176..................
1 yr. 26660.3 lb. milk; 773.49 lb. fat; 966.86 lb. butter
7 days 648.3 lb. milk; 18.10 lb. fat; 22.63 lb. butter

Oak DeKol Ollie Homestead 85529
(20–16–12–11–14)
Sire of 7 over 500 lb. fat
Johanna Fayne Rue 2d
1 yr. 21925 lb. milk; 790.57 lb. fat; 988.21 lb. butter

Wisconsin Bess Piebe Laura 97555
(4–1–3–2)
7 days 528.5 lb. milk; 23.70 lb. fat; 29.25 lb. butter
1 yr. @ 12 yrs. 15113 lb. milk; 529.47 lb. fat; 661.83 lb. butter

King Segis Pontiac Count 93909
(38–27–17–21)
Sire of 12 over 800 lb. fat or 1000 lb. butter
Princess Changeling Segis
1 yr. 31063 lb. milk; 1030.05 lb. fat; 1287.56 lb. butter

Prince DeKol Beauty Girl 98624
7 days @ 7 yrs. 591.1 lb. milk; 17.37 lb. fat; 21.71 lb. butter

Sir Ormsby Hengerveld DeKol 31212
(69–20–31–50)
Sire of: 1 over 800 lb. fat or 1000 lb. butter; 4 over 600 lb. butter

Daisy Mercedes Pietertje 53643
(3–1–4)
7 days 525.7 lb. milk; 17.43 lb. fat; 21.78 lb. butter

Alma Prince Jewel 32731
(6–3–3–6)
Sire of: Alma Lincoln Garben
14833 lb. milk
509.98 lb. fat
637.47 lb. butter

Mayhamb Pietertje DeKol 49751
(3–0–1)

has been shown to be false, and all such cases can be explained on the theory of recombination of existing factors.

Saturation.—It was also believed by many that with the persistent use of a certain sire the later offspring tended to resemble that sire more than the first ones, and also that the dam tended to become more like the sire. The theory of saturation is really a statement of the cumulative effect of telegony and there is plenty of evidence against it.

Maternal Impressions.—There is a common belief that strong mental impressions received by the dam at the time of mating or during pregnancy have in some way a specific effect upon the offspring. It has been a common practice in the past to have animals of the desired type around at the time of service so that the dam would receive the desired impression. The holding of a blanket or other object of a certain color before the dam at the time of service, in order to influence the color of the offspring, has also been practiced. There are, of course, no grounds for belief in the efficacy of these practices.

Normal Period of Gestation

The normal period of gestation for a cow is 283 days. Shaw[1] gives the extremes in the duration of the period of gestation in the cow as from 265 days to 300 days. Wing[2] made a study of 183 gestating females and found the average to be 280 days with the extremes of 264 to 296 days. He found that the sex of the offspring made no difference. Many breeders believe that the male requires a few days longer, on the average, than the female. Table F in the Appendix gives the gestation period of dairy cows.

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LECTURE XXIV

THE SELECTION OF THE SIRE

Importance of the Sire

According to Galton's law, one-half of the characteristics of the individual come from the male parent and his ancestors, and the other half from the female parent and her ancestors. Since in most herds only one bull is used, and he is mated with all the cows, one-half of all the characteristics of the heifers that are raised come from the sire. This has resulted in the well-known and popular statement that the sire is half of the herd. The facts are that certain excellent sires are more than half of the herd; likewise certain extremely poor ones are more than half of the herd. In other words, there are prepotent sires, both for bad and for good. Since the sire is at least one-half of the herd, it can easily be seen that the main chance for the improvement of the herd lies in the introduction of good blood by means of the sire. A good cow during any one year has but a very small influence upon the breed, as the number of offspring which she can produce is very limited as compared with the offspring of a bull. The necessity of selecting a good sire to head the herd is therefore very evident.

Methods of Selecting the Sire

The first point in selecting a sire to head a herd is that he must be a pure-bred of the breed which has been chosen. Pure-breds should have the factors for milk production concentrated to a much higher degree than grades or scrubs, since they have been bred with that in mind for a great number of years. That the animal is a pure-bred is perhaps all that need be considered in herds where the grading up has just begun; but in herds that are fairly well developed, or in pure-bred herds, more should be looked for in a sire than the mere fact that he is a pure-bred. The owners of such herds

usually adopt one of the following methods, or a combination of them, in selecting the sire to head the herd.

1. Selecting by type or general appearance.
2. Selecting by pedigree (or by pedigree and type).
3. Selecting by the production of the daughters (using proved sires).

Selecting by Type and General Appearance.—Many sires are selected simply on their type. This method can be used to advantage in the beef breeds, since they show by their conformation the qualities for beef production—the thing for which they have been bred. The dairy sire, however, bred for milk production, does not show his milk-producing qualities. He may show to a certain extent the body characteristics of his daughters, but it is questionable whether we really know the fundamental relationship between the conformation of certain parts of the body and its functions. For example, we do not know for certain that a large heart girth in a cow means a large heart and lungs, or that a large heart and lungs mean a superior constitution; nor do we know that a large barrel means a large capacity for handling feed, or that there is any relation between a sloping rump and milk production.

Milk production, as we have seen, is controlled by certain factors which are carried in the germ cell and, as far as we know, are in no way related to the body conformation of the animal. In other words an animal may be ideal as far as type is concerned and still be worthless as a producer of milk or butterfat simply because she does not carry the factors for high production. Since we know that inheritance governing all characteristics is transmitted through the germ plasm, it does not seem possible that we will ever be able to tell by the appearance of an animal what its inheritance for production is.

Breeders who are interested in showing sometimes use this method of selection, as they are more interested in type than in production. Other breeders should not lose sight of type in selecting a bull and should not use a bull, even of good breeding, unless he has some type; but selecting entirely by type will not usually result in great improvement in production.

Some characteristics, moreover, which contribute to the type and

value of dairy cows are not revealed in the conformation of the bull, but are of great importance. The following are the most important of these characteristics.

Mammary System.—It is a well-known fact that the sire is able to influence to a marked degree the conformation of his daughter's udders. Yet it is impossible to determine, by looking at a bull, just what kind of udders his daughters will have. Whether the udders will be meaty and coarse, or of good quality; whether they will be pendulous, with weak attachments, or capacious and well attached; whether they will have level floors or are quarter-cut, will be determined largely by the inheritance the sire carries for these characteristics. In like manner the sire influences not only size, shape, and placement of teats, but even the characteristics of the milk veins. When it is realized that a cow is no better than her udder, the study of type in sire selection will go farther than merely looking at the bull under consideration. It will involve the inspection of the sisters, the dam, and the granddams and their sisters. This will necessitate not only seeing those related animals which may be available, but also studying photographs of those related animals which, for some reason, cannot be seen.

Long Life.—The value of a cow is, in many cases, determined by the length of her productive period. It can safely be assumed that under normal conditions the profit above feed cost for the first two or three years of the average cow's productive life is required to pay for the cost of raising the animal to a productive age. It is generally recognized that families of cattle vary in their average length of life. The daughters of some bulls are very promising during their first lactations, then quickly pass out of the herd. On the other hand the daughters of other bulls remain profitable producers for several lactations. It is, therefore, very desirable when buying a bull to select one from a long-lived family. There is nothing about the type of a bull that will give a reliable indication in regard to the longevity of his daughters.

Persistency of Production.—It is generally accepted that dairy cows should produce milk for at least ten months of each year. Some, however, are much more persistent producers than others. This characteristic seems to be a matter of inheritance, and the

daughters of one bull persist in producing at a very high level during almost the entire lactation, whereas cows of another family are conspicuous because of their lack of this quality.

It is recognized also that the daughters of some bulls produce more heavily during their first lactation than during succeeding ones. Daughters of other bulls, however, will show an increase in production as they approach maturity, then maintain their mature level of production to an advanced age.

There is no doubt about the desirability of having cows in the herd that are persistent producers not only during the individual lactation but also from year to year. When selecting a herd sire one should seek a bull from a family of cows noted for persistent production. This cannot be determined by selecting the bull on the basis of type or body conformation alone.

Milk Yield and Butterfat Percentage.—There is some doubt in the minds of many as to any close relationship between the body conformation of a cow from a showyard standpoint and her productive ability. There is still more and perhaps better-founded doubt in regard to the existence of any great relationship between a sire's conformation and his daughter's milk-yielding ability. Furthermore, at this time there is no acceptable evidence pointing to the accuracy of selecting bulls on the basis of type that will transmit any certain level of butterfat percentage (within a breed).

Selecting by Pedigree.—Most of the sires used at the head of the herds in this country are selected by pedigree or by the combination of pedigree and type. This is the best method available for most breeders, as there are very few proved sires in the country; but, because it is impossible to secure the entire history of any animal, sometimes the method is not entirely satisfactory. For a great many years, therefore, selection by pedigree must be the principal method.

In using this method, only the most important things in a pedigree should be considered. Too much stress should not be laid upon ancestors too far back in the pedigree. The dam, the sire, the sisters, the half sisters, and, to some extent the cousins should be given consideration in the order named. The breeding ability of the dam should be given just as much attention as her record. If she has sons and daughters and all have made good records, this indicates

that she had the ability to transmit her desirable characteristics to her offspring and she should be given greater consideration than if she had only a high record with no proved offspring.

It is necessary also to consider the chance that any given individual has had. On many farms the number of cows is small and they are not pushed for high records to the extent that they would be on other farms. Therefore, more would be expected of a sire in a large herd known to have been pushed for high production than of a sire in a small herd where the animals are not pushed.

This method of selecting sires, as has already been pointed out, is not a sure one because it is impossible to get the entire history of any animal. One cannot be sure that the animal will carry the factors for milk production in a homozygous state.

"When a cow shows great producing capacity we must assume that she has at least a part of the factors in her germinal make-up that go to determine the ability for large production, otherwise she would not be a large producer—but we cannot be certain that she does not have in her germ plasm the factors that will cause low production. Then, too, the germinal make-up of the offspring of this high-producing cow will depend partly on the sire she is mated with. If the character for high production is dominant as it appears to be, then it will be difficult by basing selection on the production records of the dam to breed a strain that will be pure for high production." [1]

In the same way, the bull selected by this method may carry factors for low production. That this is true is shown by a study of the results at several of the experiment stations.

Lessons from the Pennsylvania Experiment Station.—In 1916, Beam made a study of the grade Guernsey herd at the Pennsylvania Experiment Station.[2] This herd was established in 1890, and from that time up to the time of the study only pure-bred Guernsey bulls had been used. All the daughters were raised, regardless of their quality, since the object was to study the results of the continued use of pure-bred sires alone, other factors being excluded as far as possible.

The bull whose breeding was the best, *Cora's Deputy*, proved

[1] Proc. World's Dairy Congress, 2 : 1375.

[2] Pa. Sta. Rept. 1915–1916.

to be the poorest bull that the college owned. He was prepotent in an undesirable way. *Lucretia's Glenwood Boy of Haddon* was prepotent in a desirable way. The five other bulls did not seem to have a very marked effect, one way or the other, upon the production, but with one exception they all increased it slightly.

Table LXX gives the production of the daughters of these bulls as compared with the dams of the daughters:

TABLE LXX

SUMMARY OF FIRST YEAR'S RECORD OF THE HERD SIRES USED AT THE PENNSYLVANIA EXPERIMENT STATION, 1890–1915

Name of Sire	Number of Daughters and Dams	Production of Daughters		Production of Dams		Difference in Favor of Daughters	
		Milk, lb.	Fat, lb.	Milk, lb.	Fat, lb.	Milk, lb.	Fat, lb.
Faucette's Wonder	10	4995.0	239.2	4915.4	217.0	79.6	22.2
Warwickshire	7	4842.9	240.3	4452.1	215.9	309.8	24.4
Cora's Deputy	29	4063.6	197.3	4938.4	250.6	−874.8	−53.3
Selectrina's College Boy	38	4993.6	246.1	4745.9	239.5	147.7	6.6
Success of Avon	15	4742.0	256.1	4584.0	240.2	158.0	15.9
Lucretia's Glenwood Boy of Haddon	13	5085.1	263.6	4602.7	231.4	482.4	32.2
Glenwood of Mapleton	34	4857.6	257.7	5011.9	259.3	−154.3	−1.6

It will be noted that *Cora's Deputy* reduced the production of the herd, on the average, by over 50 pounds of butterfat, and also that *Glenwood of Mapleton* caused a slight falling off. All the other bulls brought about a slight increase in the average production of the herd.

It should be realized that in a herd of only twenty cows a bull like *Cora's Deputy* means, from twenty daughters, 1000 pounds of butterfat less yearly. This amount of fat, valued at 40 cents a pound, would mean $400 loss annually. One could well afford to pay a good sum for a bull that had the ability to add this amount to the profits of the herd.

Lessons from the Missouri Experiment Station.—The Jersey herd at the University of Missouri was established in 1884. In

that year the institution purchased four registered Jersey cows and a herd bull of St. Lambert breeding, known as *Missouri Rioter.* Since that time the herd has not been increased by the purchase of females; new blood has been introduced only by the purchase of bulls, and since 1892 complete milk and butterfat records have been kept for every cow. In 1908 one of the authors [1] of this book made a study of the breeding of this herd. At that time five bulls had been used. Records of four other bulls have since been studied.[2] Table LXXI, prepared in a similar manner to the one for the Pennsylvania Station herd, shows the results of the use of these bulls.

TABLE LXXI

A COMPARISON OF PURE-BRED JERSEY SIRES IN THE UNIVERSITY OF MISSOURI HERD

Name of Sire	Number of Daughters and Dams	Production of Daughters		Production of Dams		Difference in Favor of Daughters	
		Milk, lb.	Fat, lb.	Milk, lb.	Fat, lb.	Milk, lb.	Fat, lb.
Missouri Rioter	4	4381	216	5380	234	− 999	−18
Hugorotus	11	4576	216	4969	231	− 394	−15
Lorne of Meridale	12	6050	291	4559	221	1491	70
Missouri Rioter 3rd	3	8005	384	4775	238	3230	146
Minnattes Pedro	20	5376	271	5321	268	55	3
Daisy's Prince of St. Lambert	....	3932	198	5362	269	−1430	−71
Brown Bessie's Registrar	....	4607	229	6069	300	−1460	−71
Fairy's Lad	....	6169	323	6219	299	−50	24
Sultana's Virginia Lad *	....	7722	445	5349	277	2373	168

* Records in all cases for this bull are two-year records.

Of the nine bulls used at the head of this herd, four were poor, two medium, and three good, from the standpoint of their influence upon the production of the herd. *Missouri Rioter* decreased the average production of his daughters below that of their dams by 999 pounds of milk and 18 pounds of fat. His son, however, *Missouri Rioter 3rd*, caused an increase of 3230 pounds of milk and 146

[1] Am. Breeders' Ass'n, 6 (1910).

[2] Hoard's Dairyman, 51: 230. Dairy Cattle and Milk Production, Eckles.

pounds of butterfat yearly for each daughter over the dam. The value of such a bull in a herd cannot be estimated. If he had twenty daughters in the herd and they were milked one year, the increase in milk production over that of their dams would be 64,600 pounds. If this milk is worth $2 per hundred, the income for milk over that which the dams would produce would be $1292. If these daughters remained in the herd for the number of years that the average cow remains, which is five, it is easy to figure the increased income which would result from one year's service of such a bull.

Brown Bessie's Registrar had a very good pedigree. As far as his pedigree was concerned, there was every reason to expect excellent results from his use. His daughters, however, were failures. They averaged 1460 pounds of milk and 71 pounds of butterfat less than their dams. If there were twenty of his daughters in a herd for a year they would decrease the milk production from that of their dams by 29,200 pounds of milk and 1420 pounds of butterfat. This bull was a serious detriment to the herd. Similar lessons can be drawn with other sires, with varying results. No credit has been given for increased sale value of the offspring of the better sires, although this may be as much as or even more than the profit due to the increase in production.

Lessons from the South Dakota Experiment Station.—The South Dakota Experiment Station [1] has also presented data showing the differences found in pure-bred sires. Table LXXII shows the results of the use of five different pure-bred Holstein-Friesian sires at that station.

For *Sir Korndyke Bess Piebe*, the average production of daughters is for pure-breds only; for the others the production of grade animals is also included. When *Sir Korndyke Bess Piebe's* production is made comparable, he is seen to have about the same prepotency as *Sir Cornucopia Prince* in transmitting high milk and butterfat production.

In comparing these sires the price of 40 cents a pound for butterfat was used. On this basis it was found that each pure-bred daughter of *Sir Cornucopia Prince* was worth, as a butterfat producer, $70.23 more than her dam. The pure-bred daughters of

[1] S. D. Exp. Sta. Bul. 206.

TABLE LXXII

A COMPARISON OF PURE-BRED HOLSTEIN-FRIESIAN SIRES IN THE SOUTH DAKOTA EXPERIMENT STATION

Name of Sire	Production of				Difference in Favor of Daughters	
	Daughters		Dams			
	Milk, lb.	Fat, lb.	Milk, lb.	Fat, lb.	Milk, lb.	Fat, lb.
Sir Cornucopia Prince........	11,593.6	398.3	8,145.0	296.1	2448.6	102.2
King Colantha Clothilde 2nd..	11,055.8	370.0	11,340.4	393.9	−284.6	− 23.9
Sir Dakota Colantha Rue Brookings................	7,642.3	272.6	10,411.2	355.9	−2768.9	−183.3
Brookings Cornucopia........	8,039.9	296.5	9,167.3	331.2	−1127.4	− 44.7
Sir Korndyke Bess Piebe.....	16,113.9	525.8	9,382.0	307.9	6731.9	217.9

Sir Dakota Colantha Rue Brookings were worth, on the average per year, $30.02 less than their dams. The money value, from the standpoint of fat production only, between these two sires, was $100.25 for each pure-bred daughter sired. That is, each daughter sired by *Sir Cornucopia Prince* was worth $100.25 more each year than each daughter of *Sir Dakota Colantha Rue Brookings* for fat production alone, not considering the additional value for the sale of stock.

From these three studies it can be seen that the method of selecting by pedigrees is not always reliable, although it is still the best method available for most herds. Great care should be exercised, however, in selecting a bull to head the herd.

Selecting by the Production of the Daughters.—The method of using only sires that have proved their ability to increase the production of their daughters over that of the dams is the safest method to follow. Men who have well-developed herds cannot risk the chance of failure which is incurred in other methods of selection.

Until recently, however, the common practice has been to use a sire at the head of a herd for only two or three years and then sell him to the butcher. In that way the bull was gone before his value was known. This is done frequently even at the present time. However, dairy-herd improvement associations, breed associations, and

many individual breeding establishments are now attempting to prove bulls and to keep them in active service as long as possible if they are proved good.

It must not be considered, however, that all sires are desirable even though they have been proved. Some may transmit low production; others, being heterozygous for the character of high milk production, give some high-producing offspring and some low-producing offspring. The really worthwhile bull is one that transmits the character of high milk production to all his daughters, regardless of the production of their dams. Such a bull is homozygous, or pure, for high milk production. He is the prepotent sire. A bull's hereditary make-up should probably not be estimated from the producing capacity of less than six daughters. This is because the cow also exerts an influence upon the offspring, and therefore, if a sire is mated only to good animals it is often a difficult matter to determine his hereditary make-up.

Table LXXIII[1] gives an example of a prepotent sire.

TABLE LXXIII

AN EXAMPLE OF A PREPOTENT SIRE

Daughters			Dams			Difference in Favor of Daughters		
Milk	Fat		Milk	Fat		Milk	Fat	
Pounds	Per Cent	Pounds	Pounds	Per Cent	Pounds	Pounds	Per Cent	Pounds
14,191.8	5.09	724.7	8219.7	5.85	482.3	3971.9	−0.76	242.4
12,869.4	5.35	690.3	8503.1	4.63	385.3	4366.3	0.72	305.0
11,153.6	4.81	537.2	7728.9	5.09	393.2	3424.7	−0.28	146.0
11,190.8	5.79	635.6	9079.8	5.83	521.4	2111.0	−0.04	114.2
9,522.9	4.85	462.2	6979.8	5.72	389.3	2543.1	−0.87	72.9
9,133.7	5.59	498.7	8918.4	4.59	410.4	215.3	1.00	83.3
Av. 11,343.7	5.25	591.5	8238.3	5.29	430.3	3105.4	−0.04	161.3
Percentage increase or decrease						37.69	−0.76	37.46

[1] Jour. Dairy Sci., 8: 391.

FIG. 53.—Beda's May King. A famous Guernsey sire. He had nine daughters that averaged over 500 pounds butterfat during their first lactation period. Five of them are here shown. (*Hayward.*)

FIG. 54.—Eva's Beda, daughter of Beda's May King, 8566.2 pounds milk; 517.83 pounds butterfat.

Fig. 55.—Madge, daughter of Beda's May King, 9094.4 pounds milk; 448.68 pounds butterfat.

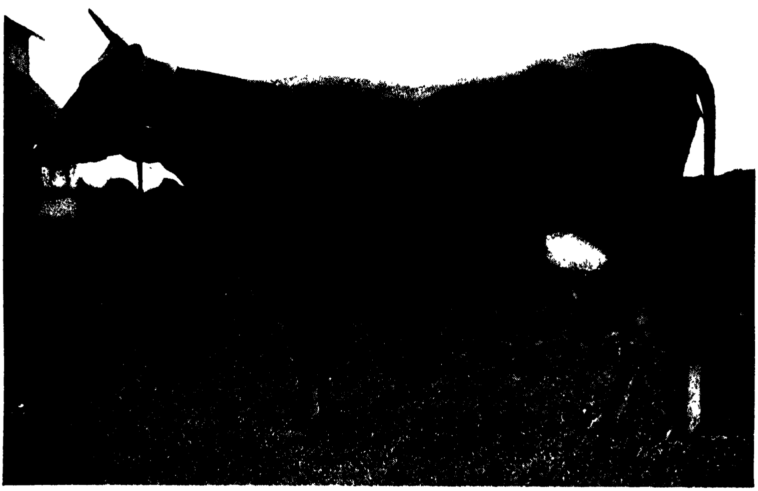

Fig. 56.—Golden Rose, daughter of Beda's May King, 9661 pounds milk; 538.94 pounds butterfat.

FIG. 57.—Red Clover, daughter of Beda's May King, 8817.5 pounds milk; 476.32 pounds butterfat.

FIG. 58.—Ruth, daughter of Beda's May King, 11,167.2 pounds milk; 599.88 pounds butterfat.

This sire increased the milk-producing capacity of each daughter. The percentage of fat was decreased in all but two cows, but the decrease was not sufficient to offset the increase in milk. Consequently every daughter showed an increased yield of butterfat.

The number of really prepotent sires that are found in any of the breeds is very small, and any such animal, when found, should be kept in service just as long as possible. Hover [1] made a study of the Guernsey bulls that entered the advanced registry up to 1915. He found that only one in one thousand is likely to make a marked improvement in the breed. This does not mean that many bulls cannot improve herds. It has reference only to prepotency that will increase the average production of the whole breed. Hover found that whereas as many as 254 sires had produced one or more "equivalent to 600-pound" daughters, only thirty-two of them had produced as many as three. In other words, he found that thirty-two sires, or only 12.6 per cent of the total number of sires of 600-pound daughters, have three or more such daughters. He makes the following statement:

"When we observe that these thirty-two sires are only 0.092 per cent of the male animals registered in the American Guernsey Herd Books, and 2.2 per cent of the 1454 sires of advanced-registry cows, the tremendous importance of the few strong sires, from the standpoint of improving the production of the breed, becomes quite apparent."

Hunt,[2] in 1921, published the results of a study of the Holstein-Friesian sires. He found that a total of 1039 sires were necessary to sire 2039 cows with a production equivalent to or greater than 600 pounds of butterfat. Only 178, or 16 per cent of these sired as many as three "equivalent to 600-pound daughters."

These examples show that certain sires are able to transmit uniformly high production to their daughters, and that others have one or two high-producing daughters while their other daughters are either average or low producers.

Sire Indexes.—In recent years several methods of calculating the breeding value of a sire in terms of milk or butterfat production have been developed. Such an index will be of great value in

[1] Jour. Heredity, April, 1916.
[2] Va. Exp. Sta. Bul. 66.

promoting the advancement of dairy-cattle breeding. The sire index based upon equal inheritance from the dams and sire, or some slight modification, is now generally used in determining the sire's index. The increase or decrease of the production of the daughters above or below the production of the dams is added to or subtracted from the daughter's records. The formula is

$$\text{Sire index} = \text{Daughter} + (\text{Daughter} - \text{Dam})$$

For example, the index of the sire in Table LXXIII would be as follows:

$$\text{Index (milk)} = 2(11{,}343.7) - 8238.3 = 14.449.1$$
$$\text{Index (fat)} = 2(591.5) - 430.3 = 752.7$$

This bull, then, would have an inheritance of 14,449.1 pounds of milk and 752.7 pounds of butterfat. His daughters will not produce this amount, however, unless he is bred to cows of equal or better inheritance. Such an index is used by the Holstein-Friesian Association. A still simpler method used by the Jersey Association does not take into consideration the production of the dam, but uses the daughter's average production as the index of the bull. This index is easy to calculate, and if one wishes to predict the performance of future daughters out of the same kind of cows, and reared and tested under the same herd environment as the daughters whose production is already known, the results will be fairly correct.

Since most indexes are based on the daughter production, the differences in herd environment exert a considerable influence upon the results obtained. The dams and daughters should be kept under similar conditions of feeding and management if the index is to be a true picture of the breeding ability of the bull. The number of individuals included will also affect the accuracy—not less than six daughters should be used; and it should be noted that all the effect does not come from a few animals. It should be understood that no index will give infallible results, but it may aid the breeder in arriving somewhere near the value of a given bull.

It is necessary, in comparing the records of dam and daughters, to adjust them to an equitable basis. Many adjustments have been proposed but only one has had general acceptance—that of the age

factor. The Jersey Association has also adopted an adjustment for the length of lactation period, and the Holstein Association adjusts the record also for times the cows are milked daily. The records are adjusted to the basis of a twelve-month lactation period for a mature cow. A ten-month record is converted by the Jersey Association to a twelve-month record by multiplying by the factor 1.15. The age factor, as worked out by the various breed associations, is given in Table LXXIV.

TABLE LXXIV

FACTORS FOR CONVERTING PRODUCTION RECORDS TO A MATURE TWELVE-MONTH BASIS.

Age, Years	Jersey Factor	Holstein Factor Milked Daily			Ayrshire Factor
		4 Times	3 Times	2 Times	
Under 2	1.45				
2–2½	1.36	1.04	1.25	1.56	1.33
2½–3	1.28	1.00	1.20	1.50	
3–3½	1.20	0.96	1.15	1.44	1.22
3½–4	1.14	0.92	1.10	1.38	
4–4½	1.08	0.89	1.07	1.34	1.12
4½–5	1.04	0.87	1.05	1.31	
5–6	1.02	0.85	1.02	1.28	1.00
6–10*	1.00	0.83	1.00	1.25	
10–12†	1.02	0.85	1.03	1.29	
12 and over ‡	1.05	0.87	1.05	1.31	
305 day factor	1.15				

* Holstein, 6–9 years. † Holstein, 10 years. ‡ Holstein, 11 years and over.

Disadvantages of Proved Sires.—Although the use of a proved sire is the surest means of permanent herd improvement, one should not purchase such a sire without considering carefully several conditions upon which his successful use depends.

1. The herd should be of a size to justify the expenditure of a sum of money large enough to buy a good proved sire. Such sires are scarce, and they often sell for high prices.

2. One should be well equipped to handle old bulls, for usually they are vicious. Strong fences and pens are necessary.

3. Because of their advanced age, proved sires need plenty of exercise. Unless a dairy farmer can provide a roomy exercising lot for an old bull, satisfactory service cannot be expected.

4. Unless a dairy farmer is inclined to be very even-tempered, he soon becomes impatient with the slow action of old bulls and decides that he can save time by using a younger, more active bull.

5. Some old bulls may be very sure breeders but will not give service every time it is needed. Under such conditions it is necessary to keep a younger, dependable bull to pinch-hit for the proved sire.

Methods of Securing Proved Sires.—It is not always possible to secure a proved bull of the type and quality that is desired, especially one that will fit into the blood lines of the particular herd at hand. Many bulls are kept in the herd only a few years, and by the time they have been proved they are no longer alive. There will probably be many more proved bulls in the future, as a result of the effort being made through the dairy herd improvement associations and through the herd improvement tests of the various breed associations. Probably, however, the supply will never meet the demand, and it will be necessary for someone to try out the young sires or else there will be no proved sires. Several methods of developing proved sires of the desired type are now being used.

1. Leasing young bulls to other breeders. For the breeder who has developed his herd to such an extent that he wishes to know what a bull will do before using him in his own herd, it is advisable that he lease him out to another dairyman who, for his use, agrees to use the bull and to test his daughters as they freshen. Many dairymen are willing to do this as they are in this way able to secure the service of a well-bred bull without the outlay of any capital. The owner of the bull should insist, however, that the bull be well fed and developed and that his offspring be tested. If he proves satisfactory he can be returned for use in his herd.

2. By breeding a few (ten to twelve) cows in the herd to a young bull and then putting the bull aside until the heifers come into milk. This method is being followed by some of the larger breeders. The bull can either be kept in the herd or, still better, leased out for use in another herd. If he is leased out, the person

who leases him need not be testing but he should be a good feeder and develop the bull to his full extent.

3. By exchanging bulls with other breeders. This method is also practiced by many breeders. Smaller breeders make the exchange by means of a cooperative bull association, many of which are in successful operation in this country.

Cooperative Bull Associations

Although cooperative bull associations have existed in Europe for many years, they were not started in this country until about 1908. In that year three such associations were started in Michigan. Since that time the movement has become widespread.

Cooperative bull associations are formed by dairymen for the joint ownership, use, and exchange of good pure-bred sires which they could not own individually. They are especially adapted for dairymen with small herds, where a valuable sire for each herd would constitute too large a part of the total investment. The organization makes it possible for such owners to unite in the purchase of one good sire, and in that way each has the use of a well-bred sire.

The cooperative bull association in this country is organized in "blocks." Each block contains from one to eight or ten dairymen and there are from three to ten blocks in one association. The average association has from three to five blocks. The association purchases as many bulls as there are blocks, and one sire is assigned to each block. As many as fifty to seventy cows may be owned by the farmers in each block, and the sire should be kept on a farm conveniently located. To prevent inbreeding, each sire is moved to the next block every two years. If the sires all live and prove satisfactory the members of the association will have the use of a pure-bred sire, at a very nominal cost, for a long period of time.

The association thus makes it possible for its members to have much better sires than they could provide individually for themselves. Furthermore, it enables them to establish a breed of livestock in their community and thus attract buyers.

These associations have brought about a vast improvement in

dairying in the communities where they have been tried, and the movement is continuing to grow.

Other Factors in Selecting a Sire

Age of Sire.—As a general rule, a young sire is preferable to an old one because he is easier to handle. Often when a sire becomes in any way unruly he is sold to a butcher. Some breeders seem to think that an aged sire is more prepotent than a young one; but our knowledge of genetics shows that nothing would be added to the germ cells with advanced age and so there could be no difference in that regard. Therefore, unless an aged sire has daughters in milk which are proving to be good producers, or daughters that will soon be tested, there is no advantage in using him. In fact, if a sire is to be purchased upon his type and pedigree, a young one should be chosen, because as a rule young sires are surer breeders and have their entire lives ahead of them. They are usually less trouble to handle than the aged sires.

Age of the Dam of the Sire.—Many people object to a sire which is the first calf of a heifer, for the same reason that they object to a young sire, namely, because they believe that he will not be prepotent. There is no reason, however, why the first calf of a heifer should not be just as prepotent as the calf of a mature cow. The only objection to such a selection is that the heifer has not had the opportunity to show what she inherits in the way of milk production. It is often unwise to select such an animal for that reason. In selecting a sire that is the calf of an older cow, one usually has an opportunity to ascertain the producing ability of the dam.

Cost of the Sire.—As has already been seen, a good sire, which will raise the production of the herd, is worth very much more than his cost is likely to be; and a poor sire, which would decrease the production of the herd, would be expensive at any price. Fraser [1] has estimated the cost of providing every heifer with one good parent, as shown in Table LXXV.

Fraser assumes that in a herd of thirty-five to forty cows there will be seventeen heifers, twelve of which are worthy of being raised; on this basis, then, and according to his valuation, each one

[1] Value of Pure-bred Sire, Fraser.

TABLE LXXV

COMPARISON OF THE COST OF A PURE-BRED AND A SCRUB SIRE

	Pure-bred	Scrub
Cost of sire	$150.00	$30.00
Interest, three years, 5 per cent	22.50	4.50
Cost of keeping, three years	100.00	100.00
Risk, three years	50.00	10.00
Total expense, three years	$322.50	$144.50
Value at the end of three years	100.00	30.00
	$222.50	$114.50
	144.50	
Extra cost, good sire, three years	$108.00	
Extra cost, good sire, one year	36.00	
Extra cost, good sire, one daughter	3.00	

of these heifers cost $3 more for having had a pure-bred sire. This takes into consideration only one year's service. Though these figures will not invariably apply, yet the lesson will be the same, viz., that in good-sized herds where the bull is used for several years it does not cost a large sum to give each heifer a good sire.

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LECTURE XXV

DAIRY-HERD DEVELOPMENT

Methods of Developing a Herd

There are two ways by which a dairy herd can be established: the first is to buy one, and the second is to breed one. Often, however, these two methods are combined, some pure-bred or high-grade animals being purchased and added to the herd already on hand which serve as foundation animals.

The best method of developing a herd, however, depends upon several factors, such as the capital available, the experience of the man starting the business, and the market for the product. In general, the man who has had no experience in the handling of dairy animals, or who has a limited amount of capital, should start with the animals he has on hand, and, by means of a pure-bred sire, breed up his herd; but the man who has had dairy experience and who has some capital, or the man who has no animals to start with, should buy a sufficient number of high-grades or pure-breds to make up all or part of his herd.

Breeding a Dairy Herd

The disadvantage of breeding a herd from a common or beef herd is that the process requires several years. However, in a locality where dairying has not been well developed, it is seldom wise for a beginner to take up the breeding of pure-bred or even high-grade dairy animals until he has had some experience in handling a dairy herd. He would perhaps be wise to take the common cows, with beef blood predominating, which he already has on his farm, and, by means of a pure-bred sire, breed up his herd. He should feed the cows a good ration, weigh the milk of each cow in his herd, and raise only the calves from the best cows. Thus, with a good pure-bred sire, he should be able to develop in several generations a

herd of high-milking cows. By the time he has developed such a herd, he will have learned the dairy business and can feed and care for his animals properly. He will also have had time to develop a market for his product. The time required for such an undertaking would be two or three generations (four to six years). Examples of such improvement have been shown at several experiment stations.

Results at the Iowa Experiment Station.—To demonstrate the improvement that can be expected from the use of a pure-bred

FIG. 59.—Herd of high-grade Holsteins graded up from common stock by the use of a pure-bred sire.

bull on a scrub herd for two or three generations, the Iowa Experiment Station [1] purchased several very inferior scrub cows and heifers and mated them with pure-bred bulls of the three breeds, Jersey, Guernsey, and Holstein. Table LXXVI shows the results secured for the first and second generations.

This table shows that the second-generation grades of the three breeds averaged 8402 pounds of milk and 358 pounds of butterfat, or an increase of 4742 pounds of milk and 186 pounds of butterfat

[1] Iowa Exp. Sta. Bul. 188.

TABLE LXXVI

TWO GENERATIONS OF GRADES COMPARED WITH THEIR SCRUB ANCESTORS. (Iowa Exp. Station)

Breed	Dams			Daughters			Grand-daughters			Increase in Production			
	Number of Cows	Av. Production		Number of Cows	Av. Production		Number of Cows	Av. Production		First Generation		Second Generation	
		Milk, lb.	Fat, lb.		Milk, lb.	Fat, lb.		Milk, lb.	Fat, lb.	Milk, per cent	Fat, per cent	Milk, per cent	Fat, per cent
Holstein.....	2	3782	176	2	6840	273	2	11,127	420	81	55	194	138
Jersey.......	2	3686	168	2	5102	241	2	5,810	301	38	43	58	79
Guernsey....	1	3463	168	1	5009	264	1	5,411	287	45	57	56	71
Average...		3660	172		5999	261		8,402	358	64	52	130	109

TWO GENERATIONS OF GRADES COMPARE WITH THEIR GRADE BEEF DAMS. (S. D. Exp. Station.)

Breed	Dams			Daughters			Grand-daughters			Increase in Production			
	Number of Cows	Av. Production		Number of Cows	Av. Production		Number of Cows	Av. Production		First Generation		Second Generation	
		Milk, lb.	Fat, lb.		Milk, lb.	Fat, lb.		Milk, lb.	Fat, lb.	Milk, per cent	Fat, per cent	Milk, per cent	Fat, per cent
Holstein.....	3	4007	165	5	7182	264	4	8315	304	79	60	108	84
Jersey.......	3	4007	165	3	5125	231	3	4732	241	28	40	18	46
Guernsey....	1	4748	193	1	5679	289	......	......	.....	20	50		
Average...		4155	171		6707	260		6268	268	61	52	51	57

over their scrub granddams. These animals were producing almost as much as the average of their breed, and their color markings and conformation were very similar to the breed, the blood of which they carried. Many were considered uncommonly good representatives of that breed.

Results at the South Dakota Station.—A similar experiment was carried on at the South Dakota Experiment Station,[1] in which grade beef animals were mated with bulls of the three dairy breeds.

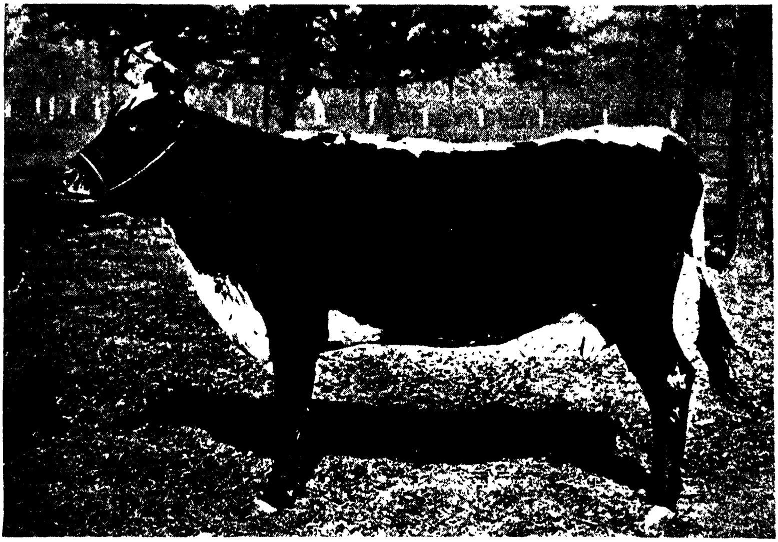

FIG. 60.—Scrub cow No. 56. Best record 4975 pounds milk; 253.1 pounds butterfat.

The cows were grade Herefords and Shorthorns. The results are given in Table LXXVI.

This table shows in unmistakable terms the fact that it is possible to grade up a high-producing herd from ordinary grade beef animals.

Results at the North Central Experiment Station (Minnesota).—In 1904, a herd of common cows was purchased at the North Central Experiment Station[2] (Minnesota), and since 1907 a pure-bred Guernsey bull has been kept at the head of the herd.

[1] S. D. Exp. Sta. Bul. 198.
[2] Minn. Ext. Circ. 15.

FIG. 61.—No. 77. Daughter of scrub cow No. 56 by a pure-bred Holstein bull. Four-year-old record: 8689.3 pounds milk; 321.31 pounds butterfat; an increase of 75 per cent in milk and 27 per cent in fat.

FIG. 62.—No. 282. Daughter of No. 77 by a pure-bred Holstein bull. Shows the typical Holstein markings.

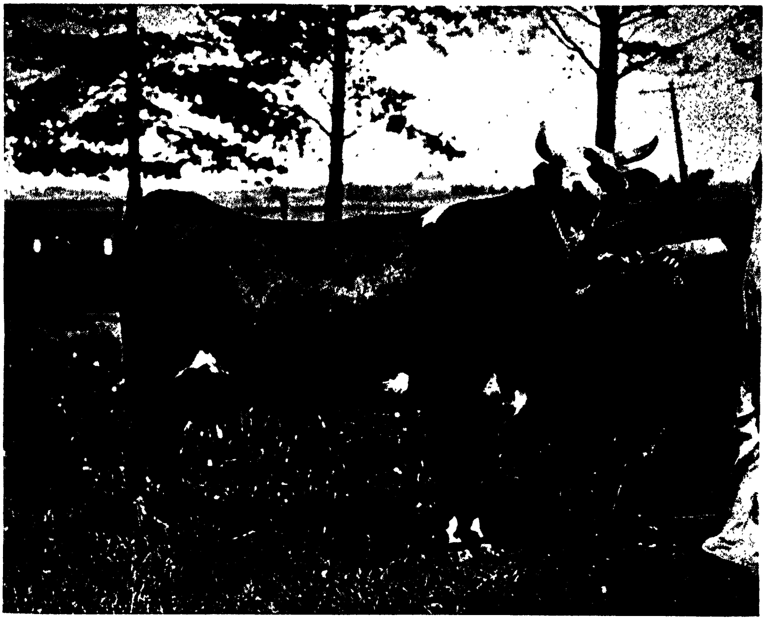

FIG. 63.—Scrub cow No. 52. Best record 4588.4 pounds milk and 201.67 pounds butterfat.

FIG. 64.—No. 69. Daughter of scrub cow No. 52 by a pure-bred Holstein bull. Four-year-old record: 6822.8 pounds milk and 283.75 pounds fat; an increase of 49 per cent in milk and 41 per cent in fat.

In 1904, the average production of the herd was only 4700 pounds of milk and 196 pounds of butterfat. The six-year average from 1911 to 1916, inclusive, was 5584 pounds of milk and 256 pounds of butterfat. The six-year average from 1917 to 1922, inclusive, was 6894 pounds of milk and 334 pounds of butterfat. This shows a gradual increase in production, the result, largely, of the use of a pure-bred sire.

These examples show what might be expected if one were to start with a scrub or common herd and develop it by means of a pure-bred sire.

Buying a Herd

The advantage of buying a herd over breeding one is that the dairyman need not wait for a number of years before beginning to make some profit. If a man knows the dairy business and has a ready market for his products, it is a waste of time to start with

Fig. 65.—No. 281. Daughter of No. 69, by a pure-bred Holstein bull. The typical markings of the Holstein are well shown.

low-producing animals. This may be necessary if the person desiring to start lacks sufficient capital to go out and purchase valuable animals, but if possible he should purchase at least a few good animals so that he will have a good herd as soon as possible.

The disadvantages of buying a herd are as follows: (1) it requires considerable capital; (2) it entails danger of disease; and (3) it is difficult to purchase good foundation cows.

Capital Required.—If one wishes to purchase good animals, one must pay a good price for them. It is true that many cows can be purchased at a low price; but these are mostly culls which some one else does not find profitable or, on account of disease or for some other reason, wishes to get out of his herd. Good cows are usually high in price and hard to purchase since no breeder wants to sell his best animals.

Disease.—The danger of purchasing animals with some disease, especially tuberculosis, Bang's disease, or mastitis, is always great. The danger of purchasing cows with tuberculosis is not as great as it was a few years ago, but still one should not overlook the possibility of this disease. Cows should not be purchased except from herds that have had a long history of freedom from this disease, and one should never purchase an animal that has not been recently tested and found free from it.

Bang's disease should be guarded against very carefully. No cow should be purchased unless it has passed a clean test; and even then it is wise to isolate it for a period of 30 to 60 days and have it retested. If a cow passes this test satisfactorily it is safe to put her with the rest of the herd. It is safer to purchase cows from accredited herds, or better still from a Bang-disease-free area.

Care should also be taken to guard against the purchase of animals affected with mastitis or other diseases.

Difficulty of Purchasing Good Foundation Animals.—Usually breeders of dairy cattle know the merits of the cows in their herd and are not willing to part with their best cows unless they are paid a good price for them. Usually the cows that are for sale are the ones that the breeder wishes to discard, because of disease, inferior milking quality, poor disposition, poor family lines, or the fact that they are not up to the standard of the herd in some other respect. It is difficult to know the entire history of an animal, and the cow that is looking her best at the time of sale may not be as good as many others in the herd which do not look so well at that time. Of course if a breeder has sufficient capital and is a good judge of cattle, he may be able to buy a good herd; but one is

never sure of just what one is getting. If records are available, the matter of production can be ascertained.

Should Foundation Stock be Calves, Heifers, or Cows?— In developing a dairy herd by buying, at least three methods are available, namely, buying calves, buying heifers, and buying cows. The choice of the individual breeder depends upon time, capital, experience, and other conditions.

The surest and quickest way to secure a high-producing herd is to buy cows with known records. This method, of course, requires a large amount of capital at the start. Ordinarily, however, it will prove more economical than buying untried animals at a considerably lower price. The trouble with selecting cows by their conformation is that the conditions under which selection is made are often very unfavorable. Some cows are dry or well on in their lactation period, others are fresh; some are thin, others are fleshy; and so it is practically impossible to select animals in this manner and be sure that they will be high producers. This method must often be followed, however, since cows with production records are few in number and a much higher price is usually asked for them than for those without records.

Perhaps the most common foundation animal is the heifer. The purchaser should obtain heifers at a lower cost than mature cows but would take chances on their being lower producers. By this method a greater number can be secured and, if good judgment is used in selection, the chance of getting a good producing herd is increased. Heifers can be purchased either bred or unbred. A purchaser who has not a good bull of his own often prefers to have the heifers bred at the time of purchase. A breeder who is endeavoring to establish a name for his own sire usually prefers to buy unbred heifers.

The cheapest way of buying a herd is to purchase calves. In many dairy sections, especially in the market-milk section, high-grade calves can be purchased at a very low price. Pure-bred calves also can often be secured at a very nominal figure. This system requires more time, however, and the chance of getting high producers may be lessened, since it is difficult to judge the individuality of the young calf. The breeder of grade stock, with little

capital, could start a pure-bred herd by buying one or more pure-bred calves each year.

Other Considerations

Breed to Choose.—One of the first questions which must be decided in establishing a herd is the choice of a breed. As a matter of fact, this decision is probably not so very important, as there is not very much difference in the efficiency of the various breeds. The dairyman should, however, decide at first which breed he wishes and then stick to his choice. If he has a common herd he should decide what breed will best fit his purposes, and then purchase a sire of that breed. The main factor to be considered is the market for the product. If he expects to sell market milk he should not choose the higher-testing breeds, such as the Guernseys or Jerseys, unless he intends to cater to a special trade which will pay for high-testing or special milk. The Holstein, Ayrshire, or Brown Swiss would usually be the choice, under ordinary conditions, for market milk. If, however, the market is for cream, butterfat, or butter, the Jersey and Guernsey should be given consideration, although if the skimmilk has a value on the farm the Holstein might also be considered.

After considering the market, one should also give some weight to such other things as the breed most common in the neighborhood, one's own preference, the cost, and the probable demand for surplus stock; but usually the market for the product will be the deciding factor.

Grades Versus Pure-breds.—Only about 3 per cent of the dairy cattle in the United States are pure-breds. This means that the majority of dairymen are content with grades and that a very large part of the milk now produced comes from grade herds. Many of our grade herds have been bred up for many generations by the use of pure-bred sires, so that they are now, to all intents and purposes, as good as pure-breds. One generation with a pure-bred bull makes them half-bred; two generations, three-fourths pure-bred; three generations, seven-eighths pure-bred; and four generations, fifteen-sixteenths pure-bred. Such animals may be just as productive as pure-breds but they cannot be registered as such.

When a dairy farmer becomes especially interested in livestock, he will prefer pure-breds to grades. Although, as has been shown, the grade animal in time could be developed so that she would be just as profitable, as far as milk production is concerned, as a pure-bred, it is impossible to register her progeny in the pure-bred herd books; and, generation after generation, the owner is just as far from having a pure-bred herd as he was at the beginning. It is usually desirable, therefore, for a breeder interested in pure-bred cattle to purchase a few good pure-bred animals and to replace the grades by pure-breds as rapidly as possible. All grades receive their good qualities from their pure blood. One should not lose sight of the fact, however, that not all pure-breds are good animals. The fact that an animal is pure-bred and is registered in a herd book does not mean that she will be any better as a producer than a good grade of the same breed. Pure-breds, on the average, may produce a little more milk or butterfat than grades, as shown in Table LXXVII, taken from the records of the New Jersey cow-testing association.[1]

TABLE LXXVII

COMPARISON OF THE PRODUCTION OF GRADES AND PURE-BREDS

	Number of Animals	Production per Cow		Feed Cost per Cow
		Milk Pounds	Butterfat Pounds	
Pure-breds	576	8862	309	$132.62
Grades	598	7989	287	124.94

This table shows that pure-breds do not produce very much more than grades. The small advantage which they have may be partly due to better feeding and care. The results of the Dairy Herd Improvement Association study shows that pure-breds produce more milk, butterfat, and income over feed costs than grades do.

An animal should be kept and bred only because of milk-producing ability, and it should be the aim of all pure-bred breeders to

[1] Hoard's Dairyman 72: 500.

discard inferior animals and not to breed or sell them to other breeders simply because they are pure-breds.

A Standard of Production.—After selecting a herd, one should attempt to improve it. The breeder cannot hope to develop and improve his herd unless he has a standard of production, which means that every cow at a certain age must be able to produce a definite amount of milk or butterfat. This definite amount must be at or above the lowest limit that is profitable under the given farming conditions. To illustrate, it might be that, under the prevailing prices in a community, a dairy cow at maturity, in order to be profitable, would have to produce 6000 pounds of milk or 250 pounds of butterfat in a year. If a mature cow is unable to do this she should be disposed of. It is usually better, however, to keep her records during her first lactation period, as this period is a very good index of her mature production. If she is unable to produce 70 per cent of the standard set with her first calf, she should be disposed of and not kept at a loss until she reaches maturity. By constantly weeding out the low-producing cows, it is possible finally to raise the average production of the herd without buying new animals, assuming, of course, that at all times there is a good sire at the head of the herd—one whose daughters, on the average, will be better than their dams. By this method the standard can be raised from year to year.

Importance of Foundation Animals.—Although, as has been noted before, great care should be taken in selecting the sire, yet it is also very important to select good foundation females. The success of the enterprise may depend upon the selection of good foundation animals. Of course, there is no way to know for certain how good an animal is as foundation stock, since much may depend upon circumstances over which the cow or breeder has no control. For example, two cows sired by the same bull were purchased at the West Virginia Experiment Station. They were both given the same chance, and both dropped four calves in the first four years they were in the herd. As it turned out, however, No. 99 dropped four heifers in that period of time, and her oldest heifer had dropped a heifer, making five females besides the cow herself in the herd. No. 98, however, dropped four bull calves and at the end of the

period had no female offspring in the herd. There is no way of foretelling such results as these.

Families do seem to inherit characteristics which make them especially valuable. Many herds have been built on the descendants of one animal, and very few herds are kept for any length of time that have not felt the influence of certain family strains. It is always wise, therefore, in selecting bulls, to pick them from families that have inheritance not only for high production but also for longevity, individual vigor, and fecundity.

Longevity.—We speak of a dairy animal as having longevity when it is able to live to a good old age and to continue to be a profitable producing animal. A dairy cow that lives and produces until she is ten years of age is about three times as profitable as one of equal production that lives until she is only six years of age. The first two years for a cow are a period of growth and not productive. It takes a second two years to pay for the feed and care required during this growing period over what she is worth for beef. This leaves then only two years of profitable production for the cow living until she is six years of age, as against six years for the one that remains in the herd until she is ten years of age. In other words, it would take three cows remaining in the herd until they are six years of age, which must be kept a total of eighteen years, to equal one cow which remains in the herd until she is ten years of age. A dairy farmer is fortunate if his dairy animals live to an advanced age and reproduce animals with the same characteristics. It seems to be established beyond question that longevity is an inherited characteristic, and that many dairy cows are born to live much longer than others. At the Pennsylvania Experiment Station,[1] in the grade Guernsey herd, which was established in 1890, only 12½ per cent of the foundation animals were able to perpetuate themselves throughout a period of twenty-six years. The blood of 87½ per cent of the foundation animals disappeared during that period. It may be of interest to note the reasons shown in Table LXXVIII for disposal of the animals in this herd.

The results of a study made in Scotland[2] of more than 3600

[1] Pa. Exp. Sta. Rept., 1915–1916.

[2] Hannah Dairy Res. Inst.

TABLE LXXVIII

REASONS FOR DISPOSAL OF ANIMALS AT THE PENNSYLVANIA EXPERIMENT STATION

	Number of Cows	Per Cent
Condemned *	15	5.9
Beef and old age	142	55.5
Barrenness	13	5.1
Tuberculosis	42	16.4
Lumpy jaw	2	0.8
Abortion	1	0.4
Died	23	8.9
No record	18	7.0
Total	256	100.0

* Records do not show why these animals were condemned—probably for tuberculosis.

head of cattle, which show the reason for disposal of the cattle in the herds of that country, are given in Table LXXIX.

TABLE LXXIX

CAUSES OF DISPOSAL OF STOCK

Reason for Disposal	Number of Animals	Per Cent of Total Disposals
Surplus stock	702	19.4
Low production	601	16.6
Hurt by accidents	55	1.5
Old age	178	4.9
Reproductive diseases	696	19.3
Udder diseases	543	15.0
Tuberculosis	275	7.6
Johne's disease	21	0.6
Bad feet	66	1.8
Death (all causes)	250	6.9
Miscellaneous	233	6.4
Total	3620	100.0

Individual Vigor.—Vigor is undoubtedly closely related to longevity. Many animals, however, may be vigorous and profitable

individuals in the dairy herd while they live, but may not last in the herd for a great number of years or perpetuate the same characteristics in their offspring. Although they are not profitable over a long series of years, yet during their own lifetime they are just as profitable as though they possessed longevity. The dairy farmer in selecting his individual animals, either at the foundation of his herd or annually, must not neglect to pay strict attention to the vigor of each one.

Fecundity.—The character of fecundity seems to be an inherited one. Some cows seem to be shy breeders, and it often happens that such a cow passes on without leaving any female offspring in the herd. This may be due to the fact that her offspring do not possess longevity or individual vigor, or it may be because the animal herself is a shy breeder or does not remain in the herd for a great length of time. Table LXXX, taken from a study of the grade herd at the Pennsylvania Experiment Station, shows the value of the cow *Handsome* as a foundation animal.

TABLE LXXX

Descendants from Original Cow, *Handsome*, in the Pennsylvania Experiment Station Herd

- Handsome....Purdie....
  - Sis.......
    - Niobe.........357
    - Sophia *....
      - 525*
      - 457*
      - 491
      - 615*
    - 337*........
      - 581*
      - Jolly
      - Jezebel
  - Jess ....Jet
  - Tease....
    - Tess........
      - 420
      - 579*
    - Titia
    - Tillie

* In herd at time of survey.

Individuals like *Sophia* or her descendants should be selected for foundation animals. *Sophia,* her sister, her dam, and the sisters of her dam, all possessed longevity and were good breeders.

Another example of the importance of foundation animals was given at the Missouri Experiment Station.[1] A Holstein herd was founded at that station in 1902 by the purchase of four pure-bred Holstein heifers; and the entire herd, which numbered more than fifty when the study was made, are descendants of this original stock. No blood on the female line had been introduced since that time. One of the heifers purchased as a foundation animal freshened twice in the herd, dropping bull calves each time. She proved to be an unprofitable producer, and, after being given ample opportunity, she was sold for beef. For this reason she left no offspring in the herd. Such a cow would make a poor start for any beginner.

A second heifer remained in the herd until she was fourteen years old and left three heifers in the herd. At the present time she has eighteen female descendants in the herd and might be termed an average cow, although very few of her descendants have been outstanding animals.

A third heifer remained in the herd for only two years, when she was condemned as tubercular. She left but one daughter, *Missouri Chief Josephine,* a cow that later won fame as the highest milk-producing college-owned cow and the second highest producer in the world. Although *Missouri Chief Josephine* was an exceptionally high producer, and although a son of hers later wielded a considerable influence in the herd, yet the female line from her is almost extinct. Only three of her female progeny are left and they are only mediocre animals. This shows that it is never safe to put all one's faith in an individual performer.

The fourth heifer, however, has had a very great influence in the development of the herd. She died with a wire in her heart at the age of five years, but left three daughters in the herd. They were all high producers and good breeders, and each left five daughters in the herd. There are now three cows of the eighth generation in the herd, and not a single generation has failed to develop a number of outstanding animals. There are at present twenty-nine female descendants of this cow in the herd. Such a cow as this would be valuable as a foundation in any herd. Table LXXXI shows her descendants.

[1] Dairy Farmer 25:10.

TABLE LXXXI

Descendants of No. 201 in Missouri Experiment Station

- 201
  - 206
    - 215
      - 228
        - 247
          - 259....500....524*
          - 271....509*
            - 529
            - 556*
        - 239
        - 256
      - 265....292....519
    - 212
    - 221....232
    - 242
      - 267
        - 285*
          - 541
          - 518*
            - 563
            - 547
          - 527*...551
          - 568*
        - 501
      - 276....513
      - 283
    - 214
  - 209
    - 227
      - 238....280
        - 504
        - 534
      - 249....278*
        - 544
        - 522....551
        - 559*
        - 567
      - 272
      - 257....282
    - 295
    - 273
      - 296
      - 297
    - 261
    - 251
      - 287....512*
      - 510*
        - 557*
        - 528
        - 564*
  - 210
    - 294
    - 263
    - 279*
      - 503*
        - 535
        - 569*
        - 520*
      - 533
      - 546*
    - 226....236
      - 275*
        - 542
        - 506
          - 532
          - 545
          - 564*
        - 511*
        - 530....555*
      - 286
        - 521*...550
        - 531*
      - 250....288*...526*
    - 220....235....260....299

* In herd at time of survey.

Effect of Housing on Longevity and Thrift.—Realizing the importance of longevity and thrift in dairy animals, several investigators have attempted to find out the effect that housing has upon these qualities. It is known that a higher percentage of the cows in the northern states, where the barns are more closely built, react to the tuberculin test than those in the states farther south, where the cows remain out for the greater part of the time and the barns are not built so tight. It has been recommended that young

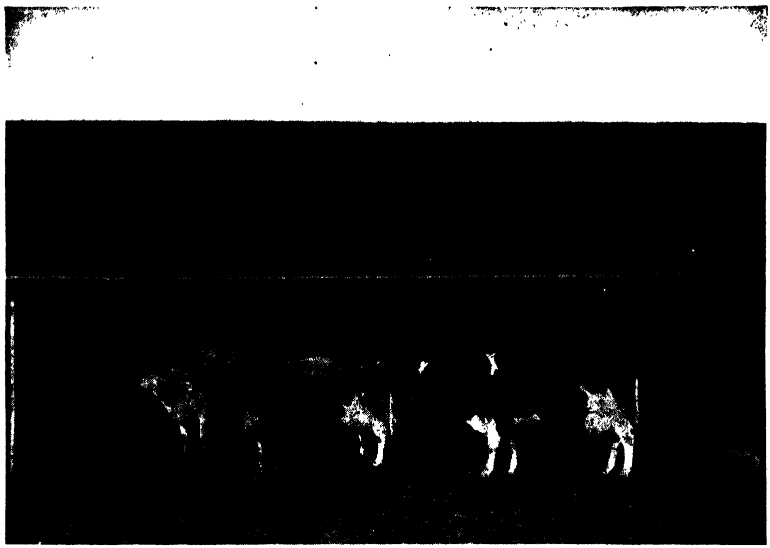

FIG. 66.—A factor in health—dairy cows housed in an open shed.

stock be housed in open sheds. Even dairy cows have been successfully housed in open sheds at the Pennsylvania Experiment Station [1] and at the Maryland Station,[2] but no studies have been made as to whether longevity and thrift will result from such methods. It was found that it required slightly more feed to produce the same amount of milk when the animals were in open sheds than when they were housed. The total amount of milk produced, however, was not much different under the two conditions. If a milking room

[1] U.S.D.A. Bul. 736.
[2] Md. Exp. Sta. Bul. 177.

is provided where the cows can be milked, the discomfort of milking in the open can be avoided.

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LECTURE XXVI

KEEPING RECORDS ON THE DAIRY FARM

NECESSITY FOR KEEPING RECORDS

A SUCCESSFUL business establishment always has a system of keeping records of transactions. Business cannot be conducted efficiently without such methods. This is just as true of the dairy business as of any other. A dairyman who does not have a fairly accurate record of the amount of feed given to the cows in his herd, and of the amount of milk and butterfat which they produce, is certainly not conducting his business upon the most efficient basis.

The actual time required to keep such records is much less than might at first be expected. Their value is clearly seen when it is realized that the selection of the herd for improved production is based upon the results of records. Cows should be valued largely by the amount of milk and butterfat that they produce. Other factors, such as regularity in breeding and ability to produce offspring of equal or greater producing power than the dam, should also be considered in placing a value on a cow. Unless accurate records are kept, the best cow in a herd is likely to have equal rank with the poorest, at least in the mind of the owner.

PRESERVATION OF PERMANENT RECORDS

One essential of records is that they be simple, though they should contain all necessary information. Many dairymen have become discouraged in the keeping of records because too complicated a system was inaugurated. As many records as possible should be final and not require copying. This is not possible with all forms of records, however.

There are three general methods of preserving records. Individual conditions will determine which one is best suited to each case. Records may be kept in any of the following ways:

1. In books with permanent leaves.
2. In loose-leaf books or files.
3. In envelopes.

There are advantages in using books with permanent leaves for some records, whereas the loose-leaf books, files, or envelopes are better for others. For breeding records, the permanent-leaf book has the advantage of being safer, as the separate pages cannot be lost; but it is cumbersome, as old records must be handled frequently and exposed to the danger of being lost if the whole book is lost. The loose-leaf records, however, may be divided and only those records that are in use at a particular time need be kept at hand, the records that are used only for reference, such as those of cattle that have gone out of the herd, being put away for safe keeping. The loose-leaf records also have the advantage that all the data relating to an individual animal may be kept together so that when it is desired to get any information upon a certain cow all such information will be together in one book. The files have the same advantages as the loose-leaf book, but are not so easily carried around, nor are they so convenient to handle.

In the envelope system, one envelope is provided for each cow, and in that envelope all records pertaining to the cow are kept. This system is not as convenient as some of the others, but is often used for the filing of registration and advanced-registry papers.

KINDS OF RECORDS

Several kinds of records may be kept on the dairy farm. Some of them are more important to the pure-bred breeder than to the breeder of grade animals. The record of production should be kept by all dairymen, however.

The important records to be kept are as follows:

1. Production records.
2. Feed records.
3. Breeding records.
4. Health records.
5. Growth and weight records.

Production Records

If one is to know the production of individual cows, two facts must be ascertained, namely, the pounds of milk produced, and the percentage of fat in the milk, from which the pounds of butterfat can be calculated. It is important that both these items be known. However, if it is possible to ascertain but one of them, the pounds of milk is much the more important. The variation between individuals is from two to five times as great in milk yield as in fat

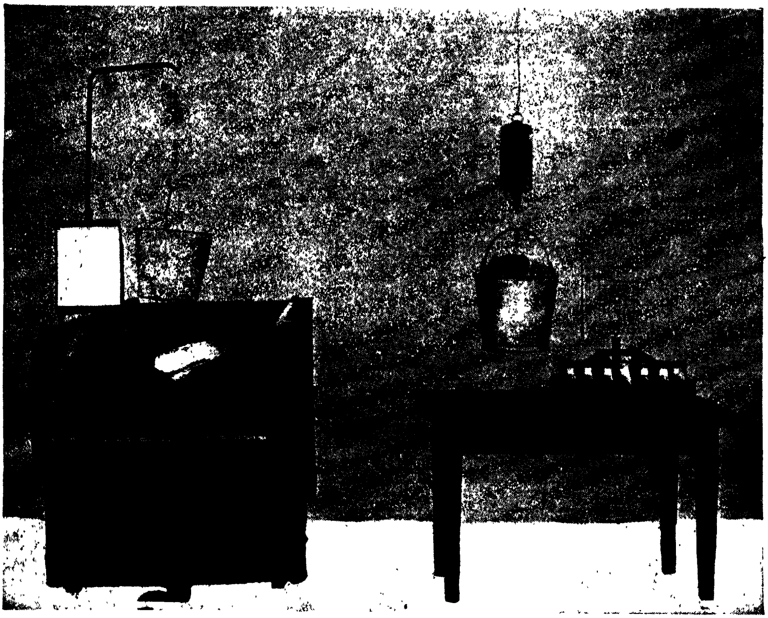


Fig. 67.—Apparatus for the determination of profit and loss of each cow in the herd.

percentage. It has been found that the milk yield usually bears a very close relationship to the butterfat yield. The high-testing cows are not always the best cows. The mere fact that a cow has a high butterfat test in no way determines that she is a profitable cow. A high test along with high milk production insures a good cow; but the high test may just as readily be accompanied by a low milk yield, and if so the cow may be an unprofitable one. Within a herd there is but little relationship between the percentage of fat in the

milk and the total milk yield. However, it is always wise, when possible, to secure a test on the cows along with the milk production. This is particularly true if the milk is being sold upon a butterfat basis, so that an exact account can be kept with each cow.

Reasons for Keeping Production Records.—The first reason for keeping accurate production records is that such records show the production of the individual cows and this may enable the dairyman to discard those that are not paying a profit and to keep the calves from those of high production. As has been brought out before, there is a vast difference in the inherent ability of different cows to produce milk. One cow may produce three times as much milk or butterfat as another, on one-third to one-half more feed. One cow may be causing the dairyman to lose as much money as another in the next stall is making for him. Cows that do not produce a profit are known as "boarder cows." Without records of production, it is practically impossible to pick out the boarder cows from those that are yielding a good income. Milkers often believe that they can tell a good producer from a poor one without keeping records of production, but this has not proved to be true. Often those selected as the best turn out to be the poorest, or vice versa. It is the production for the year that determines the value of a cow, not the quantity she may give for a few months. In order to determine her true value she must be fed and cared for throughout the entire year. Herd records show that cows that produce a moderate amount of milk persistently are usually more profitable than those that milk heavily for a few months but are dry for a large part of the year. It has been found that practically one-third of the cows in the ordinary herd are unprofitable. The milker is more likely to remember how easy a cow is to milk and how much she gives when she is fresh than how many months she will milk before going dry. It is necessary, then, to determine the actual amount of milk and butterfat that a cow produces during the year, as well as the actual amount of feed she consumes, in order to keep a complete financial balance with each cow.

Another reason for keeping a record of the milk production of the individual cow is in order to feed her properly. In a previous lecture it was stated that cows should be fed according to their production. In order to do this it is necessary to know what the

individual cow is producing. Feeding by guess is always wasteful. By means of the milk sheet, a feed chart can easily be made up at intervals and the amount fed to each individual cow can be based upon her production.

The third reason why daily records of production should be kept is that they enable the herdsman to detect any abnormal condition which may at any time occur in the herd. Often a cow suddenly becomes indisposed. The milk sheet will tell this to the herdsman at a glance. Otherwise the indisposition might go unnoticed until it developed into a serious sickness. The daily record also serves to call to the attention of the herdsman the ability of the different milkers and makes it possible to pick out those that are careless and indifferent.

A fourth reason for the use of a milk sheet is to keep up the interest of the milkers. The records of production often add considerable interest to the otherwise monotonous job of milking. The milkers and feeders are able to watch the variations on the milk sheet and will attempt to feed and milk in such a way that the production will increase, especially for those cows in which they are especially interested.

Equipment Necessary.—The equipment needed for keeping daily production records is a good spring balance, a milk sheet, and a Babcock milk-testing outfit. Besides these, some form of permanent record of production should be provided.

Scales or Balances.—A good scale to use for weighing milk is one in which the dial is divided into pounds and tenths. This style of balance is provided with a pointer which can be adjusted to stand at zero when an ordinary milk pail is hung on it. This enables the weight of the milk contained in the pail to be read directly. The scale should be hung at some convenient place near where the milker must pass in order to strain his milk.

Milk Sheet.—Close to where the scale is hung, a place for the milk sheet should be provided, so that, as soon as the milker ascertains the weight of the milk, he can easily put it down on the milk sheet. The milk sheet should be fastened on a firm, smooth wall or board especially provided for the purpose. Special holders for sheets have been devised, and are especially valuable if they are provided with a movable shield to protect the record from being soiled.

FORM A

MONTHLY MILK SHEET

A Form for Keeping Daily Milk Records for a Period of One Month

Owner of herd, ______________________; *Post Office,* __; *State,* ______________________

NAME OR NUMBER										REMARKS
1	A.M.									
	P.M.									
2	A.M.									
	P.M.									
3	A.M.									
	P.M.									
4	A.M.									
	P.M.									
5	A.M.									
	P.M.									
6	A.M.									
	P.M.									
7	A.M.									
	P.M.									
8	A.M.									
	P.M.									
9	A.M.									
	P.M.									
10	A.M.									
	P.M.									
11	A.M.									
	P.M.									
12	A.M.									
24	A.M.									
	P.M.									
25	A.M.									
	P.M.									
26	A.M.									
	P.M.									
27	A.M.									
	P.M.									
28	A.M.									
	P.M.									
29	A.M.									
	P.M.									
30	A.M.									
	P.M.									
31	A.M.									
	P.M.									
Total pounds milk,										Prices of dairy products:
Total (per cent butterfat,)										
Total pounds butterfat										
Value Whole milk, Butterfat,										
Value skim milk,										
Total value of products,										

AVERAGE DAILY FEED RECORD

Pounds,									Prices of feed:
Pounds,									
Pounds,									
Pounds,									
Pounds,									
TOTAL COST OF FEED									
INCOME ABOVE COST OF FEED,									

Some sheets record the milk production for one week, but usually a monthly sheet is preferred. This may vary considerably in detail, but Form A is a convenient one. Form B shows a sheet arranged for seven days. This form is used more often in large or experimental herds where the record of production is desired at frequent intervals. Form A, however, may have spaces for ten days' totals, which can be further added so that the monthly total can easily be ascertained. In the ordinary dairy, the monthly sheet without ten

FORM B

WEEKLY MILK SHEETS

A FORM FOR KEEPING DAILY MILK RECORDS FOR A PERIOD OF ONE WEEK

Milk Record for Week Beginning ________________ 19 ___ Milked by ________________

NAME OR NUMBER																	
Date		Lbs.	10th	Lbs.	10th	Lbs.	10th	Lbs.	10th	Lbs.	10th	Lbs.	10th	Lbs.	10th	Lbs.	10th
	A.M.																
	P.M.																
	A.M.																
	P.M.																
	A.M.																
	P.M.																
	A.M.																
	P.M.																
	A.M.																
	P.M.																
	A.M.																
	P.M.																
	A.M.																
	P.M.																
Total for week																	
Per cent. Fat																	
Pounds Fat																	

Remarks ____

Week Beginning ________________ 19 ___ Page ________________

days' total is common. These sheets can be made in any size to accommodate from five to thirty cows. The time required to weigh the milk and record it on the milk sheet need not exceed one-half minute [1] for each cow at each milking, and the value of the record obtained is worth that amount of time many times over.

[1] Farm Management, Warren.

Adding the Milk Sheet.—By totaling the milk produced by each cow during the month, her monthly production may be secured. This, however, where one does not have access to an adding machine, is a tedious task. Under such circumstances, it has been found that fairly accurate results may be obtained by adding three days of the month, say the fifth, fifteenth, and twenty-fifth, dividing the total by 3, and multiplying this by the number of days in the

FORM C

FORM FOR KEEPING PERMANENT MILK AND BUTTERFAT PRODUCTION OF INDIVIDUAL COWS

Name ______ *No.* ______ *Herd No.* ______ *Breed* ______

Year															
For Month of	Lbs. Milk	% Fat	Lbs. Fat	Lbs. Milk	% Fat	Lbs. Fat	Lbs. Milk	% Fat	Lbs. Fat	Lbs. Milk	% Fat	Lbs. Fat	Lbs. Milk	% Fat	Lbs. Fat
January															
February															
March															
April															
May															
June															
July															
August															
September															
October															
November															
December															
January															
February															
March															
April															
May															
June															
July															
August															
September															
October															
November															
December															
Yield per Period															
Number of days in Milk															
Record 365 Days															
Age at Start Test															

month. The days selected should always be well distributed throughout the month. This will give a very accurate yield for the month. Even when using this system, however, one should weigh the milk for each milking because of the many other advantages which will accrue from this habit.

Obtaining the Percentage of Fat and Pounds of Fat.—Samples for testing for butterfat should be taken at least once a month. The sample should represent at least twenty-four hours, and preferably

FORM

FORM FOR KEEPING RECORD OF INDIVIDUAL COWS

Individual Cow Record

Cow's name and number ______ *Breed* ______ *Age* ______

Testing period from ______, *19* . *to* ______, *19* *Months on test, including dry period* ______

Cow's sire { *Name* ______ *Is sire purebred?* ______
{ *Number* ______ *Is sire a bull-association bull?* ______

TESTING PERIOD	Testing day	Number of days in testing period	Pounds milk daily	YIELD DURING TESTING PERIOD: Pounds milk	Average Test	Lbs. butterfat	Price { Milk / Butterfat	Value of product $	c.	FEED CONSUMED DURING: Succulent roughage		Dry roughage			
Total to date															
Total to date															
Total to date															
Total to date															
Total to date															
Total to date															
Total to date															
Total to date															
Total to date															
Total to date															
Total to date															

BREEDING RECORD OF COW

DATE BRED	NAME OF BULL USED	PUREBRED

RECORD OF CALVES BORN DURING YEAR

Date of Birth ______

Sire ______

Sex ______

Raised or Sold ______

For what purpose ______

Selling price ______

D

IN DAIRY HERD IMPROVEMENT ASSOCIATIONS

Individual Cow Record

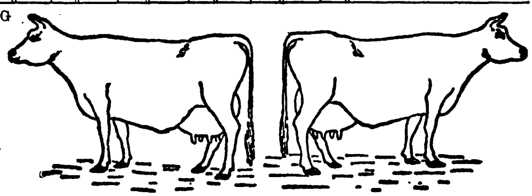
Weight ______ *Date fresh before testing year* ______ *Date bought* ______

Date dry ______ *Date fresh during testing year* ______ *Date sold* ______ *Died* ______

Cow's dam { *Name* ______ *Number* ______ *Yearly record of dam* { *Pounds milk* ______ *Pounds butterfat* ______ *Age of dam when tested, yrs.* ______ *Is the dam purebred?* ______ *Number of months in milk* ______

TESTING PERIOD						Days on pasture	Cost of pasture	Cost of roughage, including pasture		Cost of grain		Total cost of feed		Value of product above cost of feed		Value of product below cost of feed		REMARKS
Concentrates																		
								$	c.	$	c.	$	c.	$	c.	$	c.	

DESCRIPTION OR DISTINGUISHING FEATURES OF COW



forty-eight hours, of complete milking, and should be taken at fairly regular intervals.

The essential feature in taking samples of milk for testing is to obtain milk which will be representative of the whole lot. The milk should be thoroughly mixed by pouring from one vessel to another several times, after which the sample should be taken immediately. The sample should be put in a bottle, and a small amount of preservative, such as corrosive sublimate or formalin, should be added.

After the samples have been tested by the Babcock test, the percentage of fat in the milk is known. The total number of pounds of milk which a certain cow has produced during a month, multiplied by the percentage of fat in the milk, will give the total number of pounds of butterfat which that cow has given during the month.

The Permanent Record.—After the total amounts of milk and butterfat for a month have been determined, they should be put in a permanent record of some kind. Form C gives an example of such a record. It will be noted that this form is arranged so that each cow has a page and that the record can be tabulated for each lactation period. After the lactation period is finished the record can be totaled—not only for the lactation period, but also for a yearly record. An individual may also use a regular cow-testing association book for keeping such records. A page of such a book is shown in Form D. The man with a small herd, or the one who is just beginning, may use any simple notebook. The main thing is to have some permanent place to keep the records so that they may be kept in a neat and convenient form.

Method of Calculating Herd Averages.—Several methods of calculating the herd average are now in use. There is need for a standardized method so that whenever the herd average is given it will always mean the same thing.

One method of determining the herd average is on the "cow-month" basis; that is, at the close of the year the number of months each cow is in the herd during that time is determined and totaled. The total months is then divided by 12. For example, if an individual owner has 10 cows in the herd for the entire 12 months, 1 cow for 8 months, 1 cow for 6 months, 2 cows for 5 months,

3 cows for 3 months, and 3 cows for 1 month, this gives a total of 156 cow-months. This 156 cow-months, divided by 12, gives 13, or the average number of cows in the herd for the year. The total production of the entire herd is then computed; and this figure, divided by 13, gives the average herd production for the year.

This method has the disadvantage that it permits a man, by buying and selling cows, to jockey his herd so that only heavy-milking cows are kept in the herd. It might be possible to secure a herd average that was greater than that of any individual cow in the herd. Of course such cases would be very few, and with the publication of the records one can detect such manipulation.

A second method commonly used is to count in the herd averages only such cows as have been in the herd for 10 months or more.

TABLE LXXXII

CALCULATING THE HERD AVERAGE OF A HERD OF DAIRY COWS

Number of Cow	Days in Herd	Production of	
		Milk, lb.	Butterfat, lb.
1	365	10,217	408.8
2	365	10,069	357.9
3	365	6,452	257.7
4	365	7,726	307.9
5	365	8,612	294.8
6	365	9,027	296.7
7	365	11,199	439.1
8	335	11,758	415.9
9	325	9,468	345.7
10	305	6,319	237.4
Average of 10 cows in herd 305 or more days		9,084.7	336.2
11	240	5,367	217.6
12	180	3,449	101.4
13	150	4,008	110.2
14	92	3,210	102.0
15	30	980	37.3
Average of 139 cow-months, or 11.6 cows per year		9,298.3	338.8

The other cows are listed, but are not considered in the herd average. Table LXXXI illustrates the two methods.

In this herd there were 7 cows in the herd for 12 months, 2 cows for 11 months, 1 cow for 10, 1 for 8, 1 for 6, 1 for 5, 1 for 3, and 1 for 1 month, or an average of 11.6 cows in the herd for 12 months. The average production of these 11.6 cows was 9298.3 pounds of milk and 338.8 pounds of butterfat. When the method by which the cows were in for 10 months or more was considered, there were 10 cows which had an average production of 9084.7 pounds of milk and 336.2 pounds of butterfat.

Feeding Records

To know how much profit a cow is making, it is necessary to know not only the production of the cow but also the amount of feed which she has consumed. It is also necessary, especially in

FORM E

A BI-MONTHLY FEED SHEET

Number of Cow	Date											192
	Grain Ration No.——			—— Hay			Silage			Beets or Beet Pulp		
	A.M.	N.	P.M.	A.M.	N.	P.M.	A.M.	N.	P.M.	A.M.	N.	P.M.

large herds, to have some form on which to put down the amount of feed that each cow should receive. It is almost impossible for any individual to carry in his head the amount of feed that should be given to each individual cow. Usually such a record should be changed at weekly intervals but sometimes it is arranged to run for ten days or even two weeks. Form E is one that has been used suc-

FORM F

A PERMANENT FEED RECORD BLANK

Name ______ *No.* ______ *Herd No* ______ *Breed* ______

Month	Weight, Lbs.	Height, C. M.	Whole Milk, Lbs.	Skim Milk, Lbs.	Ration No.	Grain, Lbs.	Hay, Lbs.	Silage, Lbs.	Beet, Lbs.	Pasture Days	Weight, Lbs.	Height, C. M.	Ration No.	Grain, Lbs.	Hay Lbs.	Silage, Lbs.	Beet, Lbs.	Pasture Days	Weight, Lbs.	Height, C. M.	Ration No.	Grain, Lbs.	Hay, Lbs.	Silage, Lbs.	Beet, Lbs.	Pasture Days
January																										
February																										
March																										
April																										
May																										
June																										
July																										
August																										
September																										
October																										
November																										
December																										
Total																										
January																										
February																										
March																										
April																										
May																										
June																										
July																										
August																										
September																										
October																										
November																										
December																										
Total																										

cessfully. This should be filled out according to the production of the individual cows and should be fastened to the feed cart or near the feed bin. The amount of grain given on the sheet should be carefully weighed at each feeding. The roughage need not be weighed at each feeding but should be weighed at least once a month so that some idea of the amount will be obtained.

It is a good plan to number each definite grain mixture that has been fed to the herd. A permanent record of these mixtures should

then be kept so that the number of the mix may be put on the feed sheet. In this way a definite record will always be kept.

At the end of the month the amount of feed consumed may be totaled and put in a permanent record as shown in Form F. Such records are sometimes kept in the regular cow-testing association book along with the milk records, as shown in Form D. At the end of the year the total cost of the feed which each individual cow has consumed can easily be calculated.

Calf feeding requires a somewhat different form, since calves are fed whole milk, skimmilk, grain, and hay. These can easily be made to conform to the conditions.

Breeding Records

Every cow should be given several weeks of rest before freshening in order that she may be in shape for her best production before the next lactation. Unless the exact date that each cow is

FORM G

A FORM FOR HERDSMAN REPORT

DATE____________________

	NUMBER	BULL		
COWS BRED				
		SEX	WEIGHT	REMARKS
COWS CALVED				
		DISEASE	TREATMENT	
COWS SICK				
	BOUGHT	PRICE	SOLD	PRICE
MATERIAL	BORROWED	BY WHOM	RETURNED	TO WHOM

REMARKS: ____________________

SIGNED____________________

due is known, some cows will be milked too long and others will be turned dry too soon. It is also important to know the exact date of freshening so that the cow may be fed and cared for properly before and at the time of freshening. It is very important, then, that a breeding record of some sort be kept.

Since the herdsman does not always keep the books, it is sometimes necessary to have him report in order to get the necessary information on record. His report should be simple but complete. Form G is one that can be used successfully. The herdsman should put down at once the date, the cow bred, and the bull to which she has been bred. This report should then be kept in a safe place until it can be entered in a permanent record.

FORM H

FORM FOR KEEPING BREEDING RECORD OF THE HERD

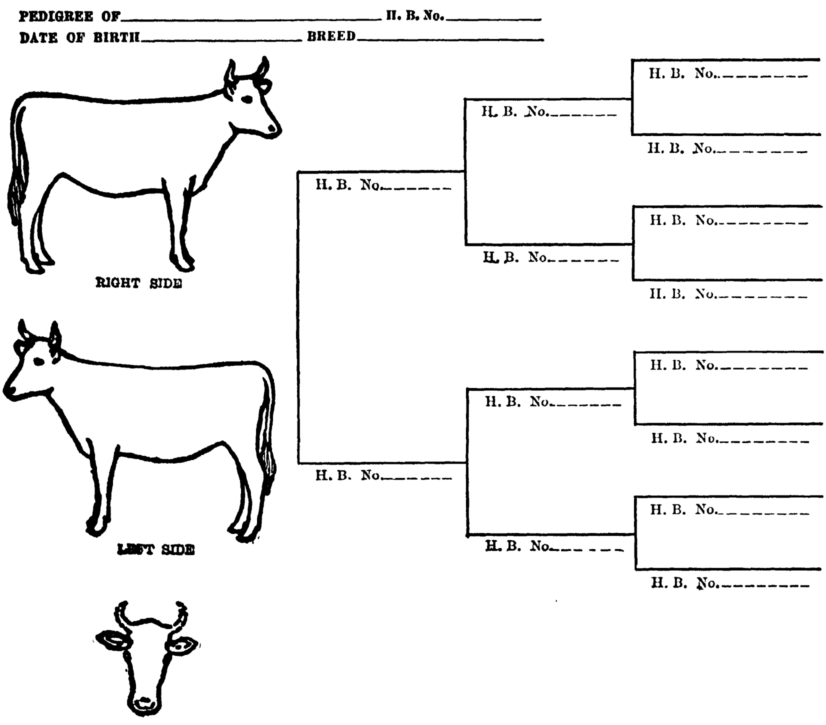
Name	H. B. No.	Herd No.	Born
Sire	H. B. No.		Color
Dam	H. B. No.		Sex
Bred by	P. O.		Breed

Date Bred	Sire	No.	Date Due 285 Days	Date Born	Weight at Birth	Sex	Name of Offspring	No.	Disposition

Form H is for the permanent record. This form also has a place for the date of birth of the calf, its sex, weight, name, and disposal. The reverse side of the sheet can be provided with pedigree and identification marks to be used especially in pure-bred herds. This is shown in Form I. It is well to put in the breeding record each

FORM I

PEDIGREE BLANK FOR HERD BOOK



breeding date so that it can be seen when a cow is a slow breeder or when she becomes sterile.

This form of record, though important with grades, is almost necessary where pure-breds are kept, as breed associations require the date on which the animal was bred, when registering it. As soon as a pure-bred calf is born, it is necessary to take the requisite steps to have it registered.

Health Records

It is often desirable to have a record of the health of the cows in the herd. This may be included in the herdsman's report and can become a part of the permanent record, as shown in Form J. This includes a place for the tuberculosis test, the abortion test, and the general health. Often, by a study of the health record of an animal, the reason for an unexpected result may be found.

FORM J

FORM FOR KEEPING A HEALTH RECORD OF THE INDIVIDUAL COW

Name________________No.______ Herd No.______Breed__________

Tuberculosis Tests		General Health				
Date	Results	Date	Disease	Treatment	Duration	Effect
Abortion Tests						
Date	Results					

Growth and Weight Record

It is often advantageous, especially with young animals, to keep a record of growth. This may consist of the weight of the animal

or its height at withers or both. By this means one can tell whether an animal is growing normally. With mature animals, the weight is of more importance. If the animal is below weight, she can be fed so that she will return to normal. The best place to keep such a record is with the feed record, as shown in Form F.

INVENTORY

Of all the records kept on the farm the inventory is the most valuable from the standpoint of keeping posted concerning the profits. In the case of fire or loss in any other way of animals or apparatus, an inventory is often of great assistance. The inventory, together with the bank balances at the beginning and end of any period, is sufficient information from which to calculate the profits.

For the inventory, a sheet with the items at the left side of the paper and several columns at the right is a good form. Opposite each item is placed the number or quantity of times, and in the first column, its value. The different columns are used for consecutive years. Such a sheet shows at a glance the relative value of each item year by year.

REFERENCES FOR FURTHER STUDY

1. Keeping Records of Dairy Cows, Eckles, Mo. Exp. Sta. Circ. 57.
2. Dairy Herd Records, Their Value and How to Keep Them, Nystrom, Wash. Pop. Bul. 97.
3. Milk Records and Tests, Emery, N. C. Agr. Exp. Sta. Bul. 116.
4. Milk Testing in Practice, Jones and Wright, S. D. Exp. Sta. Bul. 197.
5. Dairy Cattle and Milk Production, Eckles.
6. Calculating the Average Production of the Dairy Herd, Becker, Jour. Dairy Sci. 8:105.

LECTURE XXVII

PRODUCTION RECORDS

Dairy Herd Improvement Association

Although the individual dairyman, by using the method outlined in the preceding lecture, can successfully keep production records with his own herd, this has not been a very general practice, because on most dairy farms other work often interferes with a systematic and regular keeping of the records. In certain seasons of the year, especially during harvest, the testing is very likely to be neglected and the work will go undone. Furthermore, the testing and the keeping of records entail a considerable amount of figuring, and usually it will be put off until it becomes so great a task that it is never done. For these reasons many dairymen prefer to have this work done for them, and so the dairy herd improvement associations have been developed.

History of Cooperative Cow Testing.—The first cow-testing association was organized in 1895 in Denmark, where it rapidly grew in popularity. It spread throughout Denmark and other northern European countries until hundreds of such associations were formed. It has been stated that these associations more than anything else are responsible for the rapid development of dairying and the improvement of the dairy cows in these countries.

The first cooperative cow-testing association in this country was started in Fremont, Michigan, in 1905. Helmer Rabild was largely instrumental in getting this association started and was its first tester. The number of associations, later changed to dairy herd improvement associations, has grown quite rapidly and in 1937 there were 992 in the United States.

Method of Organization.—The dairy herd improvement association, as ordinarily conducted in this country, is an organization

of about twenty-six dairymen who cooperatively employ a trained man to keep a milk-production record of their cows and to test them for production of butterfat. As a tester can ordinarily test only one herd a day, the twenty-six dairy herds furnish employment for each working day in the month.

The cost of conducting such tests varies considerably. In some places the cost is based upon the number of cows which a man has to test; in others it is on a per diem basis. The dairyman usually furnishes room and board for the tester while he is at his farm.

The Tester and His Duties.—The man employed to make the tests is called "the tester" of the association. Upon his personality and ability the success of the association largely depends. He should be a man who is congenial and trustworthy; he should know how to figure the cheapest and best rations for a particular locality. He must know how to test accurately for butterfat, and be able to keep correct records. Above all, he must be industrious, accurate, and neat. The job is not an easy one, if it is well done. A good tester will do more than give a man a record of his cows.

Routine of Tester.—The tester arrives at the farm, usually before the evening milking. He weighs both the grain and the roughage given to each cow and also the milk produced by each cow. These weights are recorded, and a sample of milk from each individual cow is taken and put away until the following morning. The next morning he again weighs the feed and milk, and takes another sample of milk. These two samples are poured together and all the samples are tested. The data are then recorded, and the record of production for the month is calculated for each cow, this one day being used as the average. This is recorded in the dairy herd improvement association's book furnished by the Bureau of Dairying, which contains a page for each cow as shown in Form D. The tester makes suggestions as to the improvement of the feeding, if he can, and gives whatever other assistance may be shown to be desirable by the results of his observations.

With this record of the production and feed for one day repeated each month, the tester at the end of the year can furnish complete information about each cow. The amount of milk and fat produced during the year, the amount of feed eaten, its cost, and also the returns from each animal are computed, as well as the cost of

producing 100 pounds of milk, the return for each dollar's worth of feed, and the profit or loss above feed cost.

Number of Cows Tested.—Although this method of testing is being adopted quite rapidly, yet only a very small percentage of the cows in the country are being tested. About 2 per cent of the cows in the United States are now under test. In California the percentage is as high as 12.5, but in many of the states less than 1 per cent are being tested. About 4.8 per cent of all herds of 11 cows or more in the United States are now being tested.

Value of Cooperative Testing.—Besides the very great importance of knowing the production of each cow, the richness of her milk, and the amount of feed she eats to produce it, there are a number of other reasons why dairymen should cooperate. Dairymen, and other farmers for that matter, seem to lack the spirit of cooperation. Instead of working together to promote the industry in the entire community, they do their work separately. This is a mistake. A breeder of high-class cattle is at a disadvantage in a community where his neighbors are not also breeders of good animals. In general, the best herds and the most prosperous dairies are in localities where the farmers have cooperated and where there are many breeders of good animals in the same community. The dairy herd improvement association enables neighbors to work out these problems and difficulties together. Where there is such an association, it is easier to select cows for what they are worth than in communities where records are not kept.

The main reasons why dairy herd improvement associations are valuable are the following:

1. The "boarder" or unprofitable cow can be located and discarded. After studying many thousand records, the U.S.D.A. Bureau of Dairying has found that about one-third of all the cows in the United States are kept at a loss, another one-third just about pay for their keep, and the other one-third give a profit to their owners. If the third that is being kept at a loss could be discarded, the dairymen would greatly benefit.

2. Calves for replacement can be kept from the highest-producing cows. Unless a dairyman has production records on his cow he can never know that he is keeping calves that will maintain his production. It is next to impossible, by looking at a cow, to tell

what her production will be. Improvement of the herd depends upon keeping calves from the best cows in the herd.

FIG. 68—A "boarder cow" The owner of this cow milked her twice a day, fed, housed and cared for her for a whole year for $6 80 (*Sloan*)

FIG. 69.—A profitable cow This cow was kept in the same herd as the "border" (Fig. 68) and handled and cared for in the same way but returned a profit of $45 above feed cost. (*Sloan*)

3. Bulls can be proved. One of the greatest benefits from testing continuously is the locating and proving of bulls. The records

are sent into the Bureau of Dairying where they are tabulated, and in this way many bulls are proved. In 1936, 1187 bulls were proved by this method. Of course many of these bulls were dead, before being proved, but a system has been devised whereby the animals in the herds of the association members are given an ear tag with a number, so that they can be identified at any time. The records of cows are reported as soon as made, so that the time required for the proving of sires will be very much lessened. This method of ear-tagging will give a permanent record of all animals, and will lead to a herd analysis of each herd that is kept continuously tested for five years or more.

4. The value of the herd will be increased. Cows with records invariably sell for a better price than those without records, and a buyer may know just about what to expect from the cows he buys.

5. The cows will get better care. Men in dairy herd improvement associations invariably will feed their herds a little better and give them better care if they become interested in their records. This is shown by the fact that cows in dairy herd improvement association work produce more than twice as much as the average cow in the United States.

6. Community interest in better livestock is aroused. Very often a dairy herd improvement association will result in a widespread interest in livestock which may bring about improvement in many ways.

New Age-conversion Factors.—The Division of Dairy Herd Improvement Investigations has long been of the opinion that conversion factors based on dairy herd improvement association records would be more applicable to the cows on test than conversion factors based on any other records. The division has used the 70, 80, and 90 conversion factors which were compiled many years ago and which were based on very meager data. For several years data have been collected from dairy herd improvement association records to be used in a study of conversion factors. Sufficient data were finally obtained and a new set of conversion factors has been calculated. The data were so handled statistically that the influence of culling was reduced to a minimum.

Briefly, the plan followed was to use the percentage increase or decrease in production from year to year, or graphically, the degree

of slope of the production trend line. This trend line was derived from a great volume of data consisting of two consecutive lactation periods of the same cows. For example, the butterfat production record was obtained for the cow that freshened at the age of two and of the same cow when she freshened at the age of three. This was repeated for enough cows at these ages to furnish the production slope from two to three years of age. In order to determine the number of records necessary to give the true slope of the line from two to three years the work was continued until the slope became constant. In like manner the slope was determined for each of the other ages, that is, from three to four, from four to five, from five to six, and from six to seven, and for the intervening ages by months. These yearly slopes were then combined by statistical methods into a smooth line with all data having their proper influence in the resulting curve. Four thousand and fifty-eight individual records were used in the study, which volume is of sufficient size to insure reliable results.

The following table shows the conversion factors for the different ages:

TABLE LXXXIII

AGE-CONVERSION FACTORS

(Based on 4058 D. H. I. A. Records)

Age of Freshening		Factor	Age of Freshening		Factor	Age of Freshening		Factor	Age of Freshening		Factor
Yr.	Mo.		Yr.	Mo.		Yr.	Mo.		Yr.	Mo.	
2	0	1.294	3	0	1.149	4	0	1.064	5	0	1.020
2	1	1.279	3	1	1.142	4	1	1.059	5	1	1.018
2	2	1.264	3	2	1.135	4	2	1.054	5	2	1.016
2	3	1.250	3	3	1.127	4	3	1.049	5	3	1.013
2	4	1.236	3	4	1.119	4	4	1.045	5	4	1.011
2	5	1.222	3	5	1.111	4	5	1.041	5	5	1.009
2	6	1.211	3	6	1.103	4	6	1.036	5	6	1.007
2	7	1.199	3	7	1.095	4	7	1.033	5	7	1.006
2	8	1.188	3	8	1.089	4	8	1.031	5	8	1.005
2	9	1.176	3	9	1.082	4	9	1.028	5	9	1.004
2	10	1.167	3	10	1.076	4	10	1.026	5	10	1.003
2	11	1.159	3	11	1.071	4	11	1.024	5	11	1.002
									6	0	1.000

These factors have been tested out on records of immature cows and checked with records of the same cows at maturity and have been found to have far greater accuracy than the old 70, 80, and 90 conversion factors.

Advanced Registry Testing

When the breed associations were started, the fact that a purebred animal was registered with them was considered an evidence of superiority. However, after several years of registering in this manner, it became apparent that the law of variation operated in purebred herds just as it did in grade or scrub herds. The result was that the associations registered many inferior animals. At that time many large private records were reported by various breeders, but the word of the breeders was the only check on their accuracy. For these reasons the various breed associations conceived the idea of having a registry of dairy cows based entirely upon the individual merits of the cow, and of making the records official by having them supervised by some disinterested party.

The first of these systems in this country was established by the Holstein-Friesian Association of America in 1885. The other breed associations, seeing its possibilities, soon organized systems of their own: the American Guernsey Cattle Club in 1901; the Ayrshire Breeders' Association in 1902; and the American Jersey Cattle Club in 1903. The last-named assocation called their registry the Register of Merit; the others are called Advanced Registry. Later, the Brown Swiss Breeders' Association organized a Register of Production; the Shorthorn Breeders' Association, a Record of Merit; and the Red Polled and Dutch Belted, an Advanced Register. These are all conducted in very much the same manner and differ only in name and in requirements. Because of the cost of making these tests, the growth of such associations was naturally slow at the beginning, but after the public was educated to the fact that milk production and butterfat production are inherited characteristics, such work became popular. Today it is difficult to sell purebred individuals for a good price unless they or their ancestry have been recorded in the Advanced Registry or Herd Improvement Test.

Kinds of Tests.—Two general terms are applied to Advanced Registry tests. These terms, however, are not used with the same

meaning by different assocations. In all except the Holstein-Friesian Assocation, the term "official" is used when a test has been checked or supervised by an official appointed for that purpose. With the Holstein-Friesian Association, however, only the records made while the supervisor is present are called official, those tests made at intervals being known as semi-official.

Tests are also classified by the length of time for which they continue. For instance, there have been 7-day, 30-day, 305-day, and yearly tests. The 305-day tests also have a calving requirement. The short-time tests have given way to those extending over longer periods and are no longer conducted. The 305-day test with a calf within fourteen or sixteen months is the most popular at the present time.

With the long-time tests, the supervised period varies from one to two days a month, besides one preliminary milking for observation to see that the cow is milked dry. The fat test during this period forms the basis for calculating the fat production, and the weights of milk are used to check the weights obtained from the owner. The owner's weights may be used for other days when they are reasonably near the weights reported by the supervisor.

The Supervision of Tests.—In order to make the tests of the various associations of equal value to the public, all tests within the state are supervised by the state agricultural experiment station. If a breeder desires to test he should first get in touch with the breed association and then with the dairy department of the state experiment station, who will send a tester to supervise the test.

Objections to Short-time Tests.—The objection to the short-time test which has caused it to be completely discarded by all the breed assocations was that it did not represent the real worth of an animal. A cow can be so fed before freshening as to give abnormally high percentages of fat and thus make a good short-time record, but during the remainder of her lactation period her fat test may be so much lower that she will make but an average yearly record.

In studies by Eckles,[1] in which he tabulated the percentage of fat in milk of Holstein-Friesian cows early in the lactation period and compared the results with the average test for the year, it was

[1] Mo. Exp. Sta. Bul. 100.

found that the average for the seven days was 4.35 per cent fat whereas the average of the same cows for a year was 3.42 per cent fat. When cows are not especially fitted for such tests, the seven-day record is a fairly reliable indication of her yearly production.

Advantages of Advanced Registry Testing.—The advantages of Advanced Registry testing are much the same as those of other forms of testing already discussed. It has the further advantage, however, that it provides bulls with proved ancestry for use in other pure-bred herds and in grade herds. All the bulls in use should be pure-breds; but it is a well-known fact that not all pure-bred bulls are good ones. For this reason, only bulls with tested ancestry should be used in pure-bred or high-grade herds. Advanced Registry has provided a means of securing such bulls.

Advanced Registry has also served to prove the worth of individual sires and has kept them in use for a great many years. It has stimulated better feeding and care of animals.

Disadvantages of Advanced Registry Testing.—One of the chief disadvantages of Advanced Registry testing is that it encourages individual records rather than large herd averages. Most dairymen put on test only their best cows—those that are fairly sure to make creditable records. They then give them the best of care and attention in order to get the very largest possible production from them. The poorer cows in the herd are not tested. By this means the breeder often builds up a reputation for his herd with the aid of a few outstanding animals. A certain bull may also gain a reputation with a few high-producing daughters, though perhaps many of his daughters have not been tested and if tested could not meet the Advanced Registry requirements.

Another disadvantage of Advanced Registry testing is that, as it is commonly practiced, in order to secure the very largest production possible from individual cows, they are not bred until late in the period of lactation. In many cases the result is that the breeder is unable to have the cow bred successfully again and hence there is the loss to the breed of an otherwise excellent animal. This disadvantage has been lessened by the encouragement of the 305-day test with a calving requirement.

Still another disadvantage of Advanced Registry is that it has been an expensive method of testing. The smaller breeders could

not afford to test, and when they did test they could not afford to give the animals the care and treatment which was possible with wealthy breeders. For these reasons Advanced Registry testing did not reach as many people as it should. The expense was increased in many cases by the over-zealous supervision required to prevent fraud. This objection has recently been lessened by the reduction of the length of the test from two days with preliminary milking to one day with preliminary milking, and to the bimonthly testing in some cases.

Relation between Age and Fat Production in Advanced Registry Records

It has long been observed that milk and butterfat production gradually increase as the dairy cow matures and then gradually decrease with the onset of old age. A heifer is expected to increase in production with each succeeding lactation until she reaches maturity. The breeds do not seem to increase at quite the same rate, nor do they reach maturity at the same age. Table LXXXIV, adapted from work done at the Missouri Experiment Station,[1] gives the age-conversion factors for each of the four main breeds. Knowing the production of an animal at any age, one can easily convert it into a mature equivalent by multiplying the production by the factor for the given age.

The Herd Improvement Registry

In order to overcome some of the disadvantages of the Advanced Registry test and to increase the number of animals tested, the Ayrshire Breeders' Association started, in 1925, a test known as the Herd Test, which gives promise of being a successful means of raising the herd averages. The Holstein-Friesian Association adopted a similar test called the Herd Improvement Registry in 1927, and the other breed associations soon followed.

The primary purpose of the Herd Test or Herd Improvement Registry is to obtain records on the entire herd of the individual owner for the purpose of making definite herd improvement. It

[1] Mo. Agr. Exp. Sta. Bul. 221, and unpublished data.

TABLE LXXXIV

AGE CONVERSION FACTORS FOR DIFFERENT BREEDS WITH ADVANCED REGISTRY RECORDS

Age	Conversion Factors			
	Jersey	Guernsey	Holstein	Ayrshire
Under 2 years.....	1.484	.....	1.473	
2 - 2½ years.....	1.448	1.313	1.365	1.402
2½- 3 years.....	1.344	1.251	1.269	1.343
3 - 3½ years.....	1.248	1.194	1.196	1.283
3½- 4 years.....	1.164	1.142	1.140	1.226
4 - 4½ years.....	1.115	1.100	1.099	1.172
4½- 5 years.....	1.083	1.064	1.066	1.123
5 - 5½ years.....	1.052	1.041	1.041	1.084
5½- 6 years.....	1.034	1.023	1.023	1.050
6 - 6½ years.....	1.023	1.013	1.009	1.028
6½- 7 years.....	1.014	1.006	1.003	1.012
7 - 7½ years.....	1.008	1.000	1.000	1.000
7½- 8 years.....	1.004	1.000	1.000	1.000
8 - 8½ years.....	1.000	1.004	1.003	1.002
8½- 9 years.....	1.000	1.009	1.005	1.008
9 - 9½ years.....	1.004	1.017	1.011	1.019
9½-10 years.....	1.008	1.029	1.018	1.030
10 -10½ years.....	1.012	1.041	1.031	1.044
10½-11 years.....	1.025	1.058	1.046	1.059
11 -11½ years.....	1.038	1.075	1.064	1.077
11½-12 years.....	1.052	1.093	1.085	1.094
12 -12½ years.....	1.065	1.113	1.106	1.114
12½-13 years.....	1.093	1.137	1.131	1.135
13 -13½ years.....	1.096	1.162	1.156	1.157
13½-14 years.....	1.110	1.191	1.204	1.180
14 -14½ years.....	1.127	1.219	1.227	1.205
14½-15 years.....	1.147			
15 -15½ years.....	1.164			

permits of the testing of more cattle at a lower cost. It also permits the closer culling of herds and the early identification of superior sires. It gives an official herd average in all associations, except the Guernsey, that can be recognized by the breed associations and by the public in general.

Method of Test.—The test is conducted by the same supervisors who conduct the Advanced Registry test, and in most states

the testers employed by the Dairy Herd Improvement Association are also permitted to do the testing. The work is supervised by the state agricultural experiment stations, the same as Advanced Registry testing. The length of test is one day per month without preliminary milking; or, in some of the breeds, one day every other month with a preliminary milking. All pure-bred cows in the herd must be tested, and they can be milked either two or three times per day, or if of the Holstein breed, four times. Milk is not tested in duplicate.

Reports are sent monthly to the breed associations and at the end of the year a full report is given to the owner. This includes the production of each cow in the herd and the herd average, as computed by the methods described previously. The Guernsey Association gives only the production of the cows and not the herd average. From these data the production of the daughters of individual sires can be computed.

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8. Ups and Downs in Dairy Herd Development, a Survey of Some New Jersey Herds, Perry, N. J. Ext. Bul. 194.
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LECTURE XXVIII

FITTING DAIRY ANIMALS FOR SHOW

THE breeder of dairy cattle should consider not only the production of his cows but also their type. Production and type go hand in hand in the best breeding establishments. One of the most effective means of establishing type and of advertising a herd is by the public exhibition of dairy animals. The standard of type of the different breeds is largely set at the great exhibitions, although the classification of herds by the different breed associations is becoming more general. Although the score card is supposed to be followed at the shows, yet the different breed associations sometimes change their score cards as the result of experience secured by the competition of the animals of their breed at these exhibitions.

The great dairy shows in this country, such as the National Dairy Exposition and the different state fairs, and to a lesser extent the county fairs, are excellent educational institutions. If one wishes to become acquainted with the desired type of any particular breed, one can do so by watching the placements as made at some of the good dairy fairs.

The fairs in the United States are not conducted as they are abroad. It was the privilege of one of the authors to visit some of the agricultural fairs in Europe. At Cooper, when the West Highland Cattle Show had been in progress only one day, it was possible to buy a catalog in which could be found the placement of all the cattle in the different classes. The animals were placed the day before the opening of the fair so that even those persons who attended only the first day might know how the different classes were placed. In this country, it often happens that some of the breeds are not placed until the last day of the exhibition, and unless one remains until then it is impossible to learn all the lessons taught by actual placement in the ring. Here, however, we have the pleas-

ure of watching the judge working and of forming our own opinions of the placements before he has actually made them. Under the European system this is not possible. In this country more emphasis is laid upon advertising the breeder and less upon the educational features of the exhibition than in the European countries. However, the exhibitions in this country have recently been improved in this respect.

Two Classes of Showmen.—It is not a difficult problem for a man willing to spend large sums of money—provided he knows the

FIG. 70.—Students trimming the hoofs, clipping the hair, and polishing the horns of a cow for exhibition purposes.

type that wins, or can employ someone who does—to buy a herd of cattle that will win prizes at the shows. Such a man is known as "a fancier." Probably, so far as advertising the breed is concerned, he does as much good as though he were a breeder, but from the standpoint of permanent improvement of the breed he can do it little good. Such a person often disposes of his herd at the close of the show season, and thus no permanent good results.

A more constructive type of showman is the "breeder." The advisability of making it a prerequisite to the showing of animals

that they be bred by the exhibitor, or at least that they be in his possession many months, has been considered. The result of such a restriction would be the establishment of more breeding centers upon which the public might depend for animals that would continue to breed true to type. The breeder type of exhibitor is the one that benefits not only himself and his herd but the breed as well. He should be given all the encouragement possible.

Winning Animals.—For many years the judges at our fairs have been selected under conditions that warrant their ability to give unbiased decisions, and that compel them to be well informed about the desired type of winners. The result is that, within minor degrees of difference, the most desirable animals win today in the show ring. There was a time when breed types were less well known, judges were less carefully selected, and, as a result, the placement was somewhat of a lottery, and animals inferior in type and quality were often placed first. Fortunately, that day is past; no one can now hope to win with cattle, even though they have been well fitted, unless they possess the true breed characteristics. All animals exhibited are supposed to be typical of the breed, and this is as it should be.

Early Preparation of the Show Herd.—The man who is going to exhibit his herd on a show circuit should select among his milking animals the prospective winners—those that seem to possess in the highest degree the desired characteristics of the breed—and give them special attention, as their condition at the time of the show depends largely upon the care which they have received. In the first place it is very desirable to breed the cows so that they will freshen at the right time. It is usually best to have them freshen a short time before they are to be exhibited. They should not freshen, however, so long in advance of the fair season that their surplus fat has been milked off, so that they will look unduly thin and show lack of capacity and thrift. Sometimes animals are bred to freshen while on the fair circuit. This is often very satisfactory, as a cow usually looks her best just before and a few weeks after freshening.

It is very important, in selecting the young animals for the show circuit, that they be dropped at the right season of the year. The classes for young animals in the show ring usually include all ani-

mals within a range of six months or one year in age. The young animals should then approach the upper limit rather than the lower one, as the larger animals will always be given a preference over the smaller ones, everything else being equal.

It is well to fit several animals of each class that one intends to exhibit, as it is not always possible to determine just how an animal

FIG. 71.—Training the horns inward.

will respond to fitting until after the fitting season is over. All animals that are to be exhibited should also be tested for tuberculosis and Bang's disease, as very few fair associations allow cattle to be exhibited without first being tested.

Feeding the Show Herd.—The feeding of show animals is very important if the best results are to be obtained. It is not

desirable to have dairy animals excessively fat for exhibition purposes. It is desirable, however, for all animals to carry a fair amount of flesh, as a very thin animal will be discriminated against. The animal that is reduced in flesh will require a longer fitting period than one that is well nourished. This fact should be borne in mind when one selects animals for the show ring.

Many different grain rations can be used successfully in fitting animals for show. In general, such feeds as wheat bran, ground oats, corn meal, and linseed meal make up the larger part of the

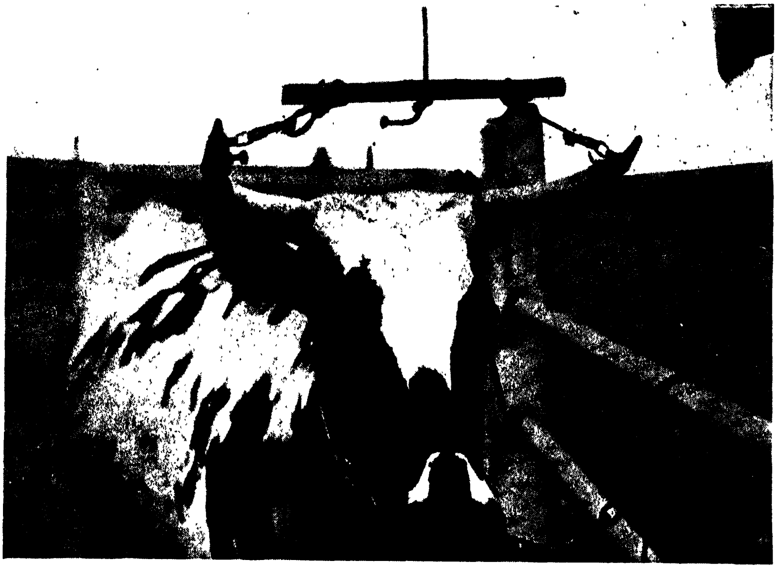

FIG. 72.—Training the horns inward and upward.

ration. The grain ration should be fed with good legume hay, silage, and beet pulp. Molasses is often fed also. The amount of grain to feed will depend upon the size, condition, and individuality of the animal. As a general rule, the cows should be fed all that they will clean up with relish. If they are thin in flesh, the amount of corn meal should be increased. Linseed meal is a very popular feed for use at this time as it seems to add a gloss to the hair and quality to the hide. Toward the end of the fitting period, beet pulp should be substituted for silage, as it is practically impossible to secure

silage on the show circuit and it is best to have the animals on the same feed that they will receive during the exhibition period.

Training the Horns.—Although animals without horns often win in the show ring over those with horns, it is, nevertheless, a distinct disadvantage to an animal not to have a good set of horns. This is especially true with certain of the breeds. An Ayrshire without horns is definitely at a disadvantage in the show ring. It is necessary, however, in order to make the best appearance, that the horns be shapely and well formed.

Certain shapes are favored in the different breeds, and it is im-

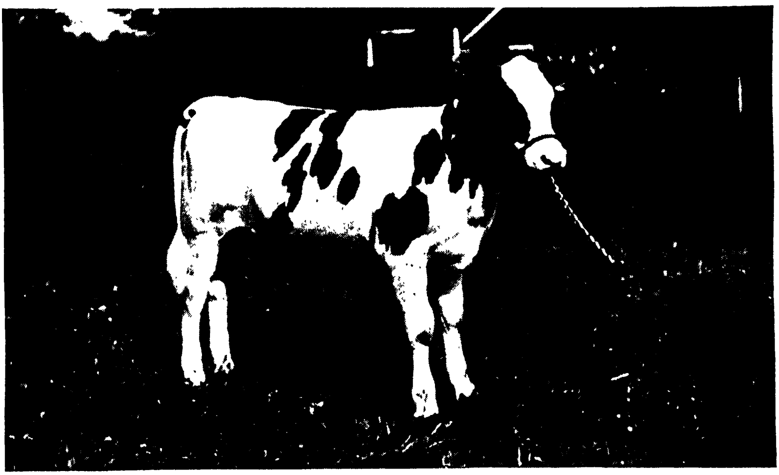

FIG. 73.—A well-trained heifer will pose itself.

portant that the horns, when they do not develop normally, be trained to grow in these shapes. Special devices have been provided in order to get the desired shape. The horns of the Guernsey, Jersey, and Holstein breeds are required to turn in. The usual means of accomplishing this result is to use a clamp which fastens on to the horns and pulls them together. With the Ayrshire breed, on the other hand, it is desired that the horns turn out and up. The apparatus for producing this effect may be of several types: each horn may be trained independently by the use of clamps, or both may be trained together by the use of clamps and weights. The clamps are fastened to the ends of the horns and pull the horns up and in.

It is very important that the training of the horns be started early so that they will be trained in plenty of time for the exhibition. The horns should be trained when the animals are between the ages of one and two years.

Training.—In order that the cattle may be shown properly in the ring, it is essential that they be given good training before starting on the circuit. Any show animal should lead readily and stand in a position that will display its good points. The younger the animal the more easily it can be taught to lead and stand properly. At any age, however, a large amount of time is required to train the

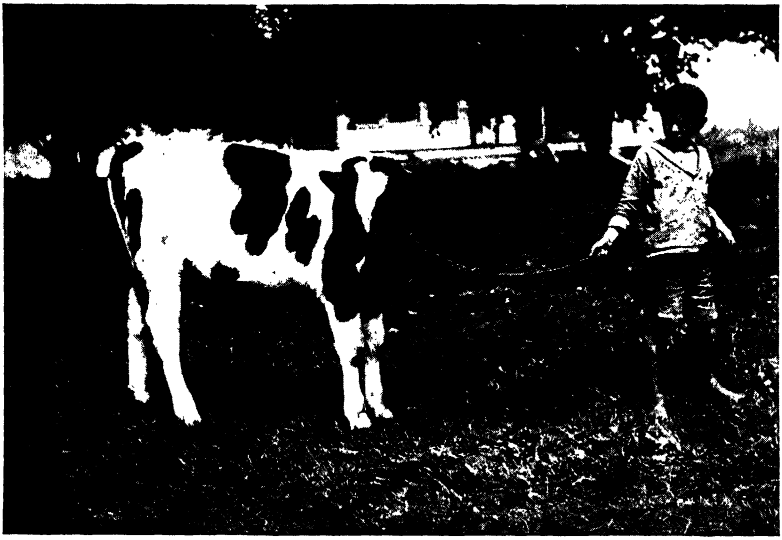

FIG. 74.—A poorly trained heifer is hard to pose.

animals to lead, back, stand, repose, or change position. Many points in posing an animal can be learned only through showing. It should be remembered, however, that all the effort expended in fitting an animal may go for naught if it is not properly trained.

Clipping.—If the hair is long, the animal should be clipped all over some weeks before showing. Care should be taken to see that the clipping is done evenly and smoothly, as a nice sleek coat adds greatly to the attractiveness of an animal.

Clipping is often done in such a way as to cover up some defect or to bring out some desirable characteristic. For example, the

hair is clipped close on the high points and left as long as possible on the low points. An uneven top line may be covered up in this way with careful clipping. The under line is often clipped as close as possible, except on the milk veins, where the hair is left a little long, in order to make the veins appear larger. The hair around the withers and the shoulders of the dairy cow should be clipped close, in order to magnify the front wedge appearance. In cattle in which dished heads are desired, the dish should be clipped very close, and on the outer margin of the dish the hair should be left a

FIG. 75.—Proper showing of the animals is very important.

little longer. This gives the appearance of a better dish. The trimming of the hair around the horns and ears demands great care. Much of the facial expression depends upon the proper appearance of these parts. The udder should be trimmed to maintain the balance of its different quarters and to make the blood vessels on its surface appear as large as possible. Animals should never be clipped and turned out on pasture, as the sun will make the hair very rough.

Brushing.—Brushing stimulates the circulation of the blood and helps to make a glossy coat of hair. A mellow skin is evidence of good feeding and thorough brushing. A common horse brush may

be used, although a stiffer brush is to be preferred. The brushes should always be kept clean.

Washing.—Frequent washing is another means of obtaining and maintaining a good condition of hide and hair. Throughout the entire fitting season the animals should be washed regularly. During the last fortnight or so before going out on the show circuit, they should be washed two or three times a week. In washing, plenty of water and soap should be used, after which they should be thoroughly rinsed. For the Guernsey and Jersey breeds, where stress is

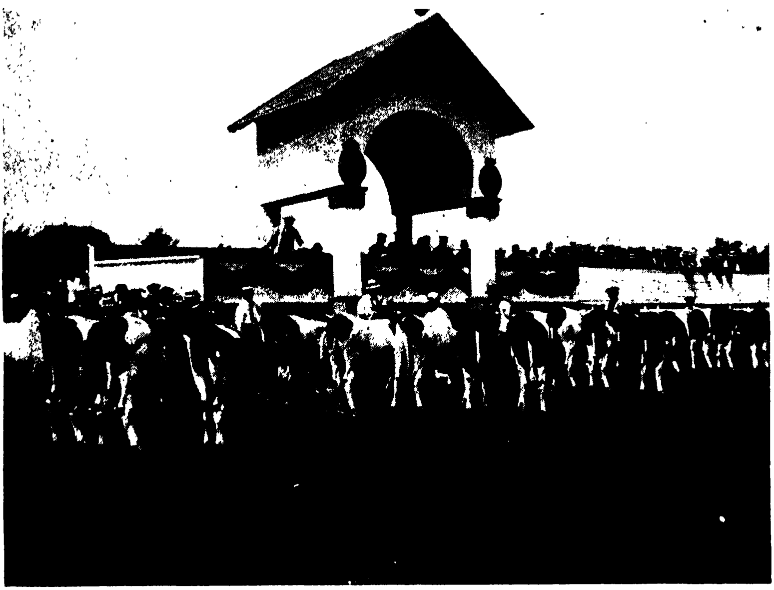

FIG. 76.—A young stock show in Denmark. (*Rasmussen.*)

placed on the yellow secretion, this washing should be done only at the beginning of the fitting period and when the animals become soiled.

Blanketing.—The animals should be blanketed after washing in order to keep the coat clean and the hide in good condition. Blanketing raises the temperature and retards the hair growth somewhat. It helps to make the coat smooth and gives an animal a smooth, finished appearance which cannot be obtained otherwise. Blanketing of show animals is universally practiced in this country.

Polishing Horns and Hoofs.—The horns and the feet of the animal have an important effect upon its appearance. The hoofs of all animals should be carefully trimmed and properly shaped. This can be done with the use of the chisel, rasp, sandpaper, and emery cloth. After the hoofs have been put in shape they should be polished with linseed oil, rubbed in with a flannel cloth or a chamois skin.

In like manner, the horns should be carefully smoothed and polished. Sometimes metal polish is applied to the horns and they are then rubbed thoroughly until they shine.

The feet and horns should be put in shape several months in advance of the show season, so that when the season approaches it will only be necessary to keep them properly polished.

Shipping.—The shipping of the animals is a very important part of successful competition on the fair circuit. The herd should be given just as much comfort as possible while being moved from one exhibition to another. Usually a car will be furnished by the railroad, to be used during the entire showing season. It is possible to prepare stalls in the car and to keep them well padded with burlap and bedded with straw so that the animals will be comfortable. The cattle should be carefully blanketed so that they will be protected from all drafts.

The person in charge of the car should provide himself with complete equipment, such as buckets, forks, shovels, etc., and with the necessary feed. He should be so equipped that he can take care of his animals without assistance from anyone.

One should always ship a show herd so that they will arrive at the place of exhibition several days before the time of showing. There will thus be ample time to get the animals in the best of shape before showing.

Final Preparations.—When the herd has arrived at the place of exhibition, care should be taken to see that everything has been properly provided. The stalls and pens should be thoroughly clean at all times, and a large amount of bedding and feed should be at hand. The entries should be carefully examined to see that they have been properly made out; the rules and methods of the particular fair should be studied and every detail carefully watched. This is particularly true for the beginner, because it may be discovered

that on account of some rule an animal will be barred from entering a class.

In order to develop the appearance of great capacity, the animals are sometimes denied water for some hours before being shown. They are given some salt, and then, before going into the ring, some water. Being very thirsty, they drink a large amount of water and hence should show a somewhat greater capacity than normal.

Bagging Up.—Animals in milk are usually brought into the show ring with distended udders. They are generally milked very little, if any, for twenty-four hours or more before being shown, with the result that the udder becomes greatly distended. This is known as "bagging up." By milking a quarter that naturally gives a little more milk than the others, a uniform effect may be given to the udder. In the large shows this practice does very little good, as the judge usually requires that the cows be milked out while in the ring. This exposes any defects of the udder, either permanent or temporary, which may have been covered up. Some exhibitors use collodion at the ends of the teats in order to keep them from leaking.

Care should be taken that the cow is not bagged too much. Many cows look better when the udder is not too much distended.

Showing.—At the call of the class, the animals should be led into the ring by an attendant, with an attractive, properly fitting halter and a strap that is not too long. It is the better practice to lead the animal, holding the halter in the right hand. From the time the animal enters the ring it should be the business of the attendant to see that it is exhibiting itself to the best advantage at all times. Exhibitors often attempt to place their animals in high or low positions, whichever is necessary to show them to the best advantage. Most judges, however, require that the animals be walked, causing them to lose any advantage thus gained.

The exhibitor should never remove his eye from the animal longer than is necessary, and should pose his animal even though the judge is not looking at the moment. When the line is ready the attendant should face the animal, taking a position that will permit him to observe both the judge and the animal. By a gentle touch of the foot it should be possible, by "previous training," to pose the animal properly at all times. The importance of proper training is in evidence at this time.

When the placings have been made the animals should be taken from the ring without a word, even though the placement has not been to the liking of the exhibitor. To be a good showman, a man must first learn to be a good loser.

Showing out of the Ring.—Breeders are appreciating more and more the value of showing the animals when they are not in the ring. There are always prospective buyers or men who are attending the shows to determine the breed of cattle they wish to develop. It is important, therefore, that such men have an oppor-

FIG. 77.—Selecting the best herd at the National Dairy Exposition.

tunity to see the animals outside the ring. This is especially true of the winning animals. It is usually profitable to have a good showman and salesman with the animals at all times when visitors are about. Unless the animals are about to be shown, the attendant should be willing to remove the blanket and show them at any time.

Classification of Herds.—Many breeders find it impractical, or at least undesirable, to exhibit their animals at the leading shows, and hence have no opportunity to measure the type of their herds. The Jersey and Holstein Breed Associations, realizing that the im-

FIG. 78.—Types of Jersey horns.

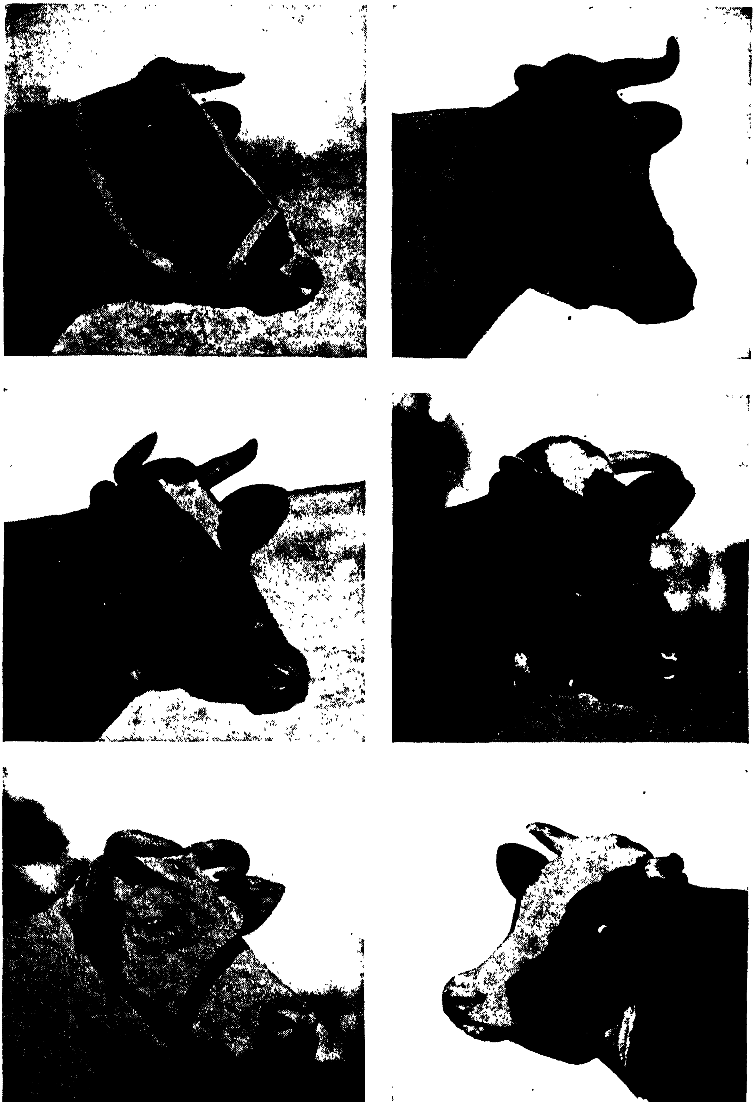

FIG. 79.—Types of Holstein horns.

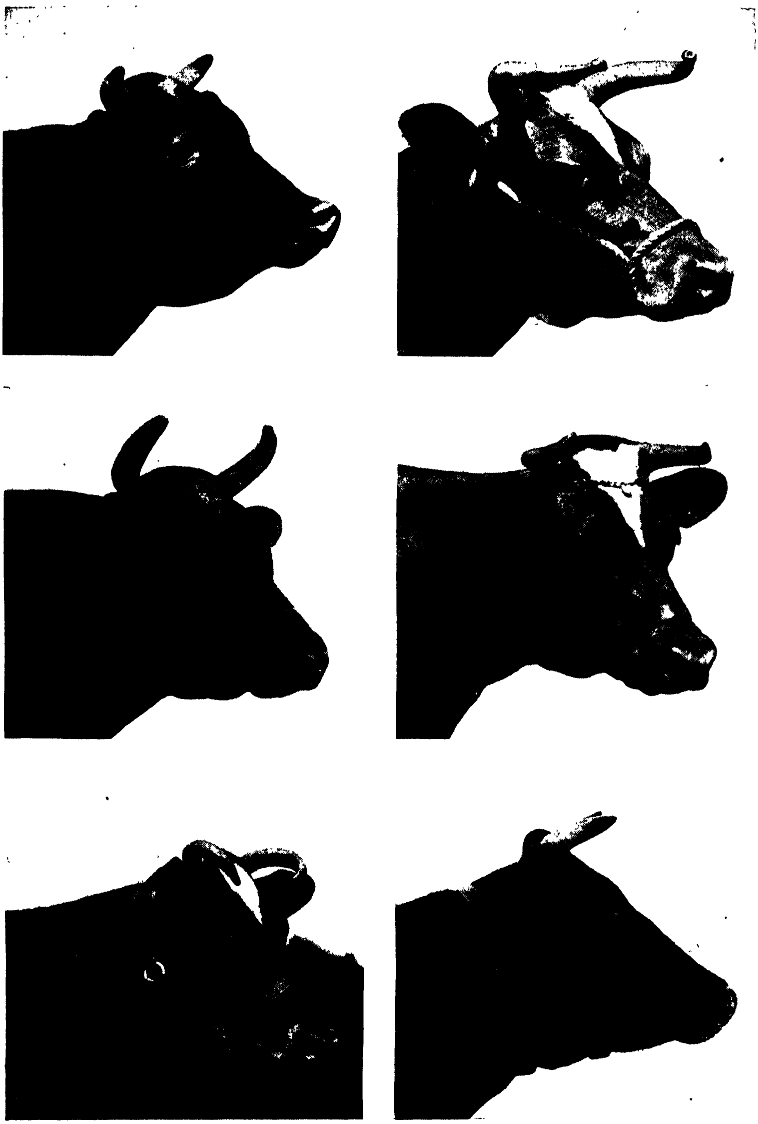

FIG. 80.—Types of Guernsey horns.

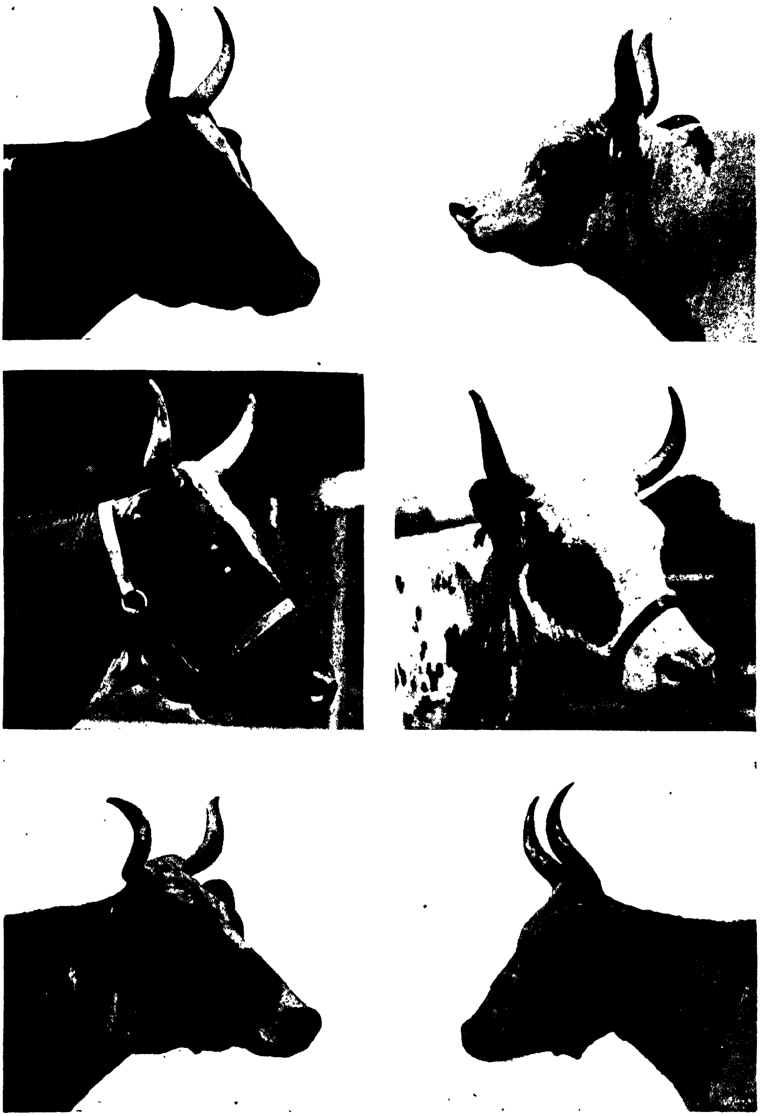

FIG. 81.—Types of Ayrshire horns.

provement of their breeds depends not only upon their production but also upon the type of the animals, have adopted plans of inspection and classification of herds. The animals in the herd are classified by a reputable judge, and are put in various classifications, such as: Excellent, Very Good, Good Plus, Good, Fair, and Poor, according as they meet the requirements of the score card. Jersey bulls can be given a double classification when 50 per cent or more of their eligible daughters have been classified, provided that not less than eight daughters of each bull are classified. The first classification represents the score of the bull and the second the highest score that will include 50 per cent (not less than eight) of the eligible daughters.

The classification of the various cows is published in the advanced registry books of the association.

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LECTURE XXIX

COMMON DISEASES OF DAIRY ANIMALS

FROM a study of the dairy records at the Pennsylvania State College it was found that 16.4 per cent of the animals were killed because of tuberculosis, 8.9 per cent died, 5.8 per cent were condemned for reasons unknown (undoubtedly in most cases for some form of disease not definitely known), 5.7 per cent were condemned for barrenness, 0.8 per cent for lumpy jaw, and 0.4 per cent for abortion. It is thus seen that a total of 37.4 per cent, or more than one-third of the animals in the herd during a period of twenty-six years, was disposed of on account of some form of disease. One of the greatest ravages of the profits of dairy farms is disease, particularly tuberculosis, abortion, and mastitis.

The dairyman and dairy student should know the symptoms of some of the most common of the dairy diseases so that they may employ preventive measures whenever necessary.

In the present lecture, a few of the most common diseases of dairy cattle will be mentioned. Usually it will be well to get the services of a veterinarian when the trouble is serious, but often help must be given before a veterinarian can be reached. One of the first treatments to give any cow when she first goes off feed is a dose of 1 to 2 pounds of Epsom salts. This should be dissolved in 3 to 4 quarts of water and given as a drench.

EQUIPMENT NECESSARY

Every dairy farmer should have a medicine chest containing the following instruments and medicines. If the herdsman has a liking for the veterinary side of the work he can profitably add to this list, but the average herdsman prefers to place serious cases in the hands of a competent veterinarian.

Clinical Thermometer.—A high temperature or an extremely low one, together with other symptoms, is an indication that the

condition of an animal is abnormal. The temperature of a cow ranges from 100 to 103° F. and may go 1° above or below these figures without causing worry. Each individual seems to have a temperature peculiar to itself. In case of fever, a rise in the temperature of 4° to 6° should have careful attention. Likewise, any falling below normal is serious. The temperature is taken through the rectum.

Pulse and Respiration.—The thermometer is depended upon by the herdsman to a greater extent than the pulse and respiration, but it is well also to consider them also. The normal pulse of the cow is from 40 to 50 beats per minute, and the respiration from 10 to 20 breaths per minute. In general, there is some relation between the two; when the pulse is fast the respiration also is fast.

Trocar and Cannula.—A trocar and cannula should always be on hand in case of an attack of bloat. One of moderate diameter should be obtained as too large an instrument cannot be used on smaller animals.

Drenching Bottle.—Medicine is usually given to a cow as a "drench" from a bottle. It is usually mixed with water. The bottle should have a long, strong neck so that it can be run back into the cow's mouth. Sometimes a glass bottle is used, but a rubber one is preferred on account of the danger of breaking the glass bottle. To drench a cow, two men are usually required. The head of the animal is raised by one of the men while the other runs the neck of the bottle into the side of the mouth between the cheek and the teeth and allows the medicine to run down into the throat. Care should be taken not to strangle the animal, as sometimes the medicine runs down into the lungs rather than into the stomach, which often proves fatal.

Milk-fever Outfit.—A profitable dairy herd cannot afford to be without a milk-fever outfit. This should always be kept in condition ready for use. If a milk-fever outfit is not available, an automobile pump and milk tube can be used as a substitute.

Milking Tubes and Teat Plugs.—Several milking and teat plugs of different sizes and lengths should always be on hand and in perfect condition.

Other articles, such as a syringe, a funnel, rubber hose, and a measuring glass, should be provided for use when needed.

Medicines.—The following medicines and disinfectants should be at hand:

Epsom salt	Creolin (or other disinfectant)
Castor oil	Tincture of iodine
Raw linseed oil	White pine tar
Vaseline	Sulphate of copper
Carbolized vaseline	Saltpeter
Boracic acid	

Common Diseases of Dairy Cattle

Tuberculosis.—One of the most important diseases of cattle is tuberculosis. Its importance is due not only to the seriousness of the disease, as it affects the animals themselves, but even more to the fact that the organism causing tuberculosis in cattle is also known to cause it in humans, especially in children under fifteen years of age.

In 1917 the Bureau of Animal Industry entered upon its active campaign to eradicate bovine tuberculosis, supported by federal, state, and county funds.

Cause.—Tuberculosis is caused by the tubercle bacillus, *Mycobacterium tuberculosis.* This bacillus gains entrance to the body and lodges somewhere in the tissues, such as the lymph glands, liver, spleen, kidney, or lungs. As the organisms grow they cause formation of small nodules called tubercles.

Although the disease itself is not inherited, there are, no doubt, certain conditions which contribute toward its development, such as a rundown state brought about by insufficient feed or heavy milk production, and environmental factors, such as poor ventilation or damp stables.

How the Tubercle Bacillus Enters the Body.—The tubercle bacillus generally enters the body by being inhaled into the lungs or taken into the digestive tract from contaminated feed or water. The disease is usually introduced into a herd by infected animals brought into a herd and passing it on to negative cattle. The bacillus may be spread from the manure of such animals, from all exhalations, from discharges, and from the milk. Such an animal is known as a "spreader," but not all animals that have the disease are spreaders. Some may have a closed type and be harmless for

an indefinite period, as far as the spreading of the disease is concerned. This type, however, cannot be distinguished from the spreader.

Cows having tubercular lesions of the udder are frequently responsible for a transmission of the disease to calves.

Symptoms.—Many animals may have tuberculosis and show no outward signs of it. As a result children consuming meat or milk from infected cows may contract the disease. Since 1917 the systematic eradication work has greatly reduced the prevalency of tuberculosis of children. The early stages of the disease pass unnoticed, and the infected cow may remain in a good state of flesh for several years. After the disease has progressed for some time the cow may lose in flesh and appetite, and gradually decline in milk secretion. Occasionally the disease will run its course rapidly and the cow will die within a short time. Usually, however, the symptoms are not marked and cannot thus be detected.

Tuberculin Test.—Tuberculin is an extract prepared by sterilizing, filtering, and concentrating the liquids in which the tubercle bacillus has been allowed to vegetate. It is absolutely sterile, and hence no harm can come from using it on healthy animals. By its use one can ascertain, in more than 90 per cent of all tests, whether a cow has tuberculosis. With extreme care, a higher degree of accuracy can be obtained. The few exceptions, however, often cause much misunderstanding.

1. *The Intradermic Test (Into the Skin).*—The intradermic test has become the standard method of diagnosing tuberculosis. In this test the tuberculin is injected between the outer layers of skin, usually at the base of the tail where the skin is soft and nearly hairless. Frequently a double injection is made. The reaction consists of a swelling, varying from the size of a pea to that of a walnut at the point of injection. It is observed at approximately 72 hours after injection.

2. *The Ophthalmic Test (Into the Eye).*—The ophthalmic test has been used only as a check test. The tuberculin, in the form of a tablet, is placed in one eye, and the other eye is used as a check. A reaction is indicated by the characteristic discharge from the eye, which may occur in from 3 to 10 hours after application.

3. *Subcutaneous Test (Under the Skin).*—The subcutaneous test

was formerly the most frequently used. It consists of injecting a certain amount of tuberculin under the skin of the animal, usually back of the shoulder. If the animal has the disease, a rise in temperature usually occurs at any time between the eighth and twentieth hours after the tuberculin is injected.

Control and Eradication.—After the disease has developed, no known treatment is satisfactory. Prior to a nation-wide adoption of the federal tuberculosis eradication program the Bang's system of isolating new-born calves from the dams was practiced in valuable breeding herds. It never gained widespread use in this country.

The Accredited-herd Plan was adopted by dairymen to establish tuberculosis-free herds. No new animals are brought into the herd, once it has an accredited rating, except from another accredited herd, or after being held in quarantine for 60 days and then tested and found free from the disease. By this means breeders can sell their stock with a guarantee that they are healthy. Such a guarantee also serves as an advertisement for their milk.

Accredited-area Plan.—Although the accredited-herd plan was useful in establishing herds free from tuberculosis, it did not in itself give a means of eliminating the disease from the country. The accredited-area plan which was adopted later (taking the county as a unit) has reduced the infection until the disease is of little economic importance. Forty-six states are reported as "accredited," and rapid progress is being made in the remaining two. To be accredited the infection in a given area must be less than 0.5 per cent of the cattle.

Since there is a tolerance of 0.5 per cent of tuberculosis in accredited areas, it can be seen that retesting at intervals is essential if tuberculosis eradication is to be successful.

Bang's Disease (Infectious Abortion).—It has been estimated that 90 per cent or more of the premature births among cattle are due to Bang's disease. Yet abortions may be due to other causes, such as injury by hooking, kicking, or falling, strong medicine, or improper feeding. As such causes are not frequent, it is always good practice to assume that every case is infectious and treat it accordingly.

Bang's disease, which was formerly known as infectious abortion, has been known for a great many years, but not until 1896

was the bacterium causing the disease discovered. *Brucella abortus,* first discovered by Bang, is now recognized as the chief causative agent; although other bacteria as well as certain protozoa and fungi have been found to be responsible for occasional abortions. Bang's disease is one of the most important diseases of dairy cattle, causing great losses every year. The damage is not due alone to the loss of the calf, but also to such factors as the loss of many cows on account of their weakened condition, retained afterbirth, and metritis (inflammation of uterus) which often leads to sterility, loss in flesh of the cows which abort, loss in the milk flow, shy breeding, lowering of the value of the animal, and extra attention required for handling an infected herd.

Symptoms.—Bang's disease is a very insidious disease and may be developing for several months before it is noted. The premature expulsion of the calf is simply an indication of the presence of the disease. For this reason, the disease may have gained quite a foothold in the herd before it is suspected. Furthermore, many cows may carry the disease and never abort. Such cows are known as "carriers" and are even more dangerous in spreading the disease than those that abort because they are not suspected. Abortion occurs most frequently from the third to the seventh month after the animal is bred. Cows of all ages are susceptible to it, but heifers most frequently abort. Some will abort the second time and a few as often as three times, after which they usually become immune to abortion and carry the calf the full time, but may still carry the germ and so be carriers. Some animals seem to be naturally immune to the disease.

Mode of Infection.—It has been quite well demonstrated that the chief mode of infection is through the digestive tract, the germs entering the system by means of the feed or water consumed. From there they are taken into the blood and are carried to the genital organs where they find conditions suitable to their development. They attack the membrane which surrounds the fetus and separate it from the maternal membrane, cutting off the circulation and thus causing the expulsion of the fetus. Formerly it was thought that the bull was the chief source of infection, but this has been disproved.

Tests for Abortion.—Two laboratory blood tests for diagnosing

this disease have been found satisfactory. These are the complement-fixation test and the agglutination test.

The complement-fixation test is complicated and for this reason has not been used extensively. The agglutination test is much simpler and, in the hands of a careful person, has been just as satisfactory. Blood testing will not foretell an abortion, but it will indicate the animals that carry *Brucella abortus* organisms.

The agglutination test is conducted by taking blood samples from the jugular vein of the cow to be tested and allowing the blood to clot. After a few hours the clot contracts and the clear liquid (serum) separates. In the laboratory the causative germs are grown and suspended in a physiological normal salt solution. Enough germs are placed in this solution to make it slightly cloudy. Measured amounts of this suspension are then placed in a series of test tubes and the serum added in such quantities that the first test will contain 1 part of serum to 50 parts of suspension, the second 1 part to 100, etc., until the desired number of dilutions are obtained. The tubes are then placed in a warm place and examined at the end of forty-eight hours. If a cow is infected her serum will cause the bacteria to agglutinate or clump together. Otherwise the suspension will remain cloudy. There are modifications of the technique used in conducting the agglutination test. The plate method which is quite common consists of adding a given amount of serum and test fluid on a plate glass and mixing the two with a glass rod. The resulting reaction takes place in a few minutes.

These are the only accurate methods of detecting the carriers. Any intelligent systematic attempt at the eradication of the disease must be conducted with some such test.

Treatment and Prevention.—No medicine has been found that has proved successful in the control of this disease. Control measures are confined entirely to herd management and sanitation. The disease may be eradicated from the herd by using the following methods with the strictest care:

1. Have the entire herd tested at frequent intervals to determine which animals carry the disease germ, and dispose of all reacting animals that are not of especial value.

2. Three weeks before any reacting animal is due to freshen, or at the first sign of an abortion, remove the animal to a separate

barn and keep her so isolated until all discharge has disappeared after freshening. This will be at least six weeks.

3. Destroy all dead calves and afterbirths by burning or burying deeply. If the cow has aborted in the barn, thoroughly disinfect the stall where she stood.

4. Have a separate attendant for such cows, or have the attendant wear different clothes when caring for them, so that the infection will not be carried on the clothes or shoes from one barn to another.

5. Before returning the cow to the regular barn be sure that she has no discharge and give her a thorough washing with some disinfectant.

6. Take care that no manure or refuse from the stall of the isolated animals is placed where the other cows can have access to it.

7. If it is not possible to have the herd tested, treat all animals in an affected herd as if they had the infection.

Herds free from the infection have been built up by isolating all reacting animals, since calves rarely retain the germ after they are weaned from the milk. They seldom become permanently infected until after they have become sexually mature. Calves from infected cows can, therefore, be put into a disease-free herd with little danger, after a short period of isolation. Testing the herd every few months is advisable, since there is a chance of a small percentage of isolated calves having a latent infection and introducing it into an otherwise negative herd.

Accredited herds which are free from this disease have been established similar to those free from tuberculosis, and several areas are also accredited. This work is just now beginning, and several years will be required before this disease will be under control in this country.

Recently a protozoan organism called *Trichomonas*, which is responsible for abortions, has been isolated from cattle in this country. Unlike Bang's disease, it is disseminated principally by the bull during service. An early diagnosis of the vaginal discharge by a diagnostic laboratory is important in preventing the spread of these protozoans.

Mastitis (Garget).—One of the worst diseases the dairyman has to contend with is inflammation of the udder, commonly called

garget. This may vary in severity from a mild case where the cow's udder swells slightly and the milk contains some clots, to a severe case where the udder is badly swollen and no milk can be gotten out of it. Very often one or more quarters are lost and occasionally the animal itself.

Cause.—This disease is generally considered due to infection with *Streptococcus agalactae*, although other organisms may be found alone or with it in cases of mastitis. *Streptococcus agalactae* is most frequently isolated from infected quarters; likewise, it may be introduced into a normal udder and result in a typical case of mastitis, although it is usually quite difficult to infect a normal udder by exposing it to injections of this bacterium. It is thought by some investigators that certain contributory factors, such as exposure to cold and wet, standing in cold drafts, injury of some form to the udder, overfeeding, sores on the teats, or insufficient stripping of the udder in milking, may be associated with the spreading of mastitis. Usually the first indication of the trouble is a thickening of one or more of the quarters or the presence of "flaky" milk. The milkers should always be on the lookout for any such symptoms and use control measures at once.

Treatment.—There is no uniformly accepted method of treatment. It may be well to give the cow a dose of Epsom salts. If the case is acute and severe, a stimulant may be indicated. The application of heat to the affected quarters constantly for a period of several hours has given good results in the early stages of garget. A bucket of very warm water, replenished as it cools, may be set beneath the udder and with hot cloths the quarter may be kept bathed continuously for several hours. If the weather is cold the infected animal should be kept in a warm place during treatment. While the hot applications are being applied to the udder, the affected quarters should be milked at frequent intervals for several hours, or until the trouble subsides.

In dealing with the more chronic cases of mastitis, especially where a number of animals are infected in the herd, it is necessary to use preventive measures. In order successfully to prevent and control the disease, it is necessary to determine which animals are infected. This may be done by a veterinarian or by having laboratory tests conducted. Common laboratory tests are the brom thymol

blue and the Hotis, although other tests are often used. Animals found to be infected should be isolated or disposed of. Until infected animals can be removed from the herd they should be milked last. This procedure may reduce the possibility of carrying the bacteria to the non-infected cows. Sanitary precautions, such as clean hands and milking equipment, keeping the cows, as well as the dairy barn, as clean as possible, should be observed. Some dairies determine by means of strip cups whether or not the cow is giving good milk, before milking.

The use of vaccine and bacterins is receiving considerable attention. However, this treatment alone has not proved uniformly efficient. The injection of certain chemicals, particularly acradine derivatives, has given fairly good results; yet they cannot be relied upon to control mastitis effectively.

Milk Fever.—Formerly this was a very serious disease and most animals that contracted it died. Milk fever is really a misnomer, as there is no fever when the animal has this disease, the temperature really being below normal. The disease usually occurs only after calving and then generally only in high-producing animals. Very seldom does it attack heifers at the first or second calving. It is indicated by staggering, dullness of the eyes, and a falling temperature. The cow becomes paralyzed and falls down. Usually she will lie on her side with her head turned to one side, or lie on her sternum with the muzzle pointing toward the flank.

Cause.—When a heavy-milking cow begins to form milk, the calcium, sugar, and other constituents of the blood are drawn out faster than they can be replenished. When the blood calcium falls below a certain level, paralysis develops. Since there is a deficiency of calcium in the blood, the veterinarians often use 250 cc. of calcium gluconate, given intravenously, as the treatment.

The air treatment is the oldest and still the most common method of treating milk fever. By means of a milk-fever outfit the udder can be pumped up with air to cause a back pressure, which keeps the blood from entering the udder. This quickly relieves the condition. It may be necessary to pump the udder up a second or even a third time, but usually once will be sufficient. After the udder is distended until it is as hard, or nearly as hard, as a bicycle tire, the teats should be tied with tape to keep the air from escaping. The

milk should not be removed from the udder before pumping. The main objection to the use of this method is the danger of introducing an infection into the udder. This can largely be prevented by sterilizing the milk-fever outfit just before using it.

Medicine should never be given a cow when in this condition as her throat is partially paralyzed and the medicine may go down the windpipe and cause pneumonia.

Bloat.—Whenever dairy cows are turned into clover, alfalfa, or any other leguminous pasture, care must be taken to guard against bloat. In pasturing cattle on leguminous crops, it is best not to turn them into the pasture until after the dew or rain has dried off. Cattle that have been kept on such pastures for a period of time are not so susceptible to bloat as those newly pastured. Any condition of feed which causes an unusual amount of fermentation, such an amount in fact that gases are created faster than the blood can carry them off, will bring about bloat. In feeding soiling crops, the half-dried material often brings about this condition.

Treatment for severe cases of bloat consists in the use of the trocar and cannula; the animal should be tapped on the left side, halfway between the hip joint and the last rib. The best position to take in tapping is to stand at the animal's left side with the trocar pointing toward the heart. If a trocar and cannula are not at hand, an ordinary pocket knife may be used, but the cannula is preferable as it retains the opening and allows the gas to pass off as it forms.

In mild cases of bloat, the treatment is to give a physic, and to use various devices to help the animal to pass the gases out by way of the mouth. This may be done by prying the mouth open, by holding the head high, or even by inserting a rubber tube.

Foot Rot.—Foot rot is an infectious disease, generally occurring between the toes of cattle. Most dairy farmers are troubled to a certain extent by this disease. When once a farm has had a case, it is difficult to eradicate it. This disease spreads very rapidly in muddy yards. The first symptom is lameness which, together with the characteristic odor, is sufficient to show the presence of foot rot.

The first thing to do is to clean the affected part thoroughly, washing it with a strong solution of disinfectant, and to keep the infected animal in a clean, dry place. Powdered copper sulphate,

dusted over the affected part or dissolved to form a paste or 5 per cent solution and then put on, has proved very satisfactory.

Many ill-shaped hoofs are the result of this trouble.

Cowpox.—Blisters containing a yellow fluid on a cow's udder are signs of cowpox. This disease is not generally very serious and does not give the animals much pain but does cause the milker a great deal of inconvenience. The milker can spread it from one cow to another, especially if there are any scratches on the cows' udders. For this reason cows having cowpox should be milked last, or the milker should thoroughly disinfect his hands after milking a cow with the disease before milking any other cow. The milker, if he has not been vaccinated, and has a scratch on his hand, may vaccine himself against smallpox by milking a cow with cowpox. A satisfactory remedy for this disease is to apply carbolized vaseline or zinc ointment to the affected parts.

Actinomycosis (Lumpy Jaw).—This disease is caused by a fungus, *Actinomyces*, which gains access to the animal tissue and is supposed to be directly traceable to certain forms of fungus that grow on plants or grasses. It may appear in many parts of the body, although it is most commonly found on the jaw, perhaps because it can find access by way of the teeth. The disease is not very infectious.

So long as the infection is in the soft tissue it is less serious, and the growth can be cut away by a surgical operation which removes all diseased portions. This should be done by a veterinarian. When the disease has advanced until the bone is affected, little can be done. Some degree of success has been obtained by the administration of iodide of potassium, but this must be given in the early stages of the disease.

Difficult Parturition.—Cases of difficult parturition are comparatively few, and it is best not to interfere with a cow in the act of calving unless it is definitely apparent that assistance is needed. The normal presentation is the appearance of the fore legs with the head in a straight line over them. When this presentation occurs as it should, it is seldom indeed that the cow needs any help. Sometimes other presentations occur, such as the failure of one fore leg to appear, or the hind legs may come first, etc. In such cases the herdsman can often render sufficient assistance.

In more complicated cases, unless the herdsman has had experience with other cows, he may need the assistance of a veterinarian. Much care should be taken in giving assistance to a cow. When assistance is given by pulling, it should be done slowly and only when the cow is cooperating.

Removing Afterbirth.—It occasionally happens that the afterbirth of an animal is retained, on account of its connection being firmly attached to the womb. This is especially common after abortion. Unless the afterbirth is removed, serious complications may arise.

If the afterbirth has not come by itself within twenty-four to thirty-six hours, it should be removed either by the herdsman or by a veterinarian. Care should be taken in removing the afterbirth that the cow is not injured in any way.

Teat Trouble.—Teats often become scratched or cut. Carbolized vaseline, creolin solution, or hydrogen peroxide will prove satisfactory remedies. Care should be taken to remove from the pasture and lots everything which will cause scratches.

Leaky teats are very hard to cure, and a veterinarian should be called to judge the possibilities of curing them. Nothing can be satisfactorily done for them while the cow is giving milk. Collodion will close them up from one milking to the next, but such a treatment is not satisfactory.

A condition known as "closed teat" sometimes occurs at the end of the teat. Sometimes this is spoken of as "spider teat." It is simply the forming of scar tissue at the opening. At the time of each milking, this should be treated with vaseline and a disinfectant.

Silver and wax plugs are used at times on hard milkers. These may stretch the sphincter muscle at the end of the teat, and by so doing cause the cow to milk more easily. Milk tubes are often employed on hard milkers, but they should be used with care, and should always be thoroughly disinfected beforehand. Also, the muscle may be cut by special teat instruments; the result is sometimes satisfactory but more often it is not. Only a veterinarian should perform this operation.

Common Calf Ailments

Common Scours.—Common scours is one of the ailments that occur most frequently in calves. The most frequent cause of scouring is overfeeding. If the calves have not been overfed, the condition can probably be traced to feeding from dirty pails, feeding cold and warm milk alternately, feeding sweet and sour milk alternately, feeding milk too rich in fat, irregular feeding, or unsanitary and damp pens. The first symptom usually noted is a stain on the tail of the calf, caused by semi-fluid and foul-smelling discharges, after which it can be noted that the calf is listless and has little appetite.

Prevention of this trouble is easier than its cure. A dose (1 to 3 ounces) of castor oil should be given in order to move the bowels properly. This may be followed by 1 teaspoonful of a mixture of equal parts of salicylic acid and tannin, twice daily, until the symptoms are removed. Care should be taken in getting the calves back on full feed, so that they will not come down with another attack. Although common scours is not considered infectious, it is good practice to keep sick calves away from the other calves, so that they can be given better treatment.

White Scours.—White scours is an infectious disease caused by a germ which enters the body, most frequently through the digestive tract. It attacks calves at birth or soon thereafter. The symptoms are dullness, weakness and prostration, sunken eyes, short hurried breathing, and a low temperature, the calf lying on its side with the head resting on the ground. The discharges of the bowels are profuse, yellowish white, and very offensive in odor. The disease is usually fatal within 1 to 3 days after birth.

Prevention is the best means of combating white scours. All cases should be isolated, the carcasses of the dead calves burned, and the stable thoroughly disinfected. When the herd is small, the disease can usually be prevented by removing the dam to clean quarters a few days before the time of freshening and keeping her there for four or five days afterward. With large herds this is impossible. Some degree of success has been obtained by injecting anti-white-scours serum into all calves immediately after birth. This, how-

ever, must be done just as soon as the calf is dropped, otherwise it is not successful.

Pneumonia.—Pneumonia is brought on by exposure and is sometimes associated with calf scours. It is characterized by lack of appetite, rapid breathing, constipation, and high temperature (105° to 106° F.). Severe attacks are usually fatal. The calf should be blanketed and placed in a clean, well-ventilated box stall which is free from drafts. Some stimulant is often given. A mustard plaster may be applied over the lungs and a laxative given to keep the bowels open.

Inflammation of the Joints.—This trouble sometimes occurs in young calves within the first month after birth. It is caused by infection which enters the body through the navel and settles in the joints. The joints become swollen and are hot and tender. The calf becomes stiff and lame, loses appetite, has a high fever and accelerated breathing, and often discharges at the navel. Treatment of the navel of the new-born calf with tincture of iodine at the time of birth will usually prevent this trouble.

Ringworm.—Ringworm is a fungous growth quite common in calves. Besides detracting very much from their appearance, it affects the thrift of the animals. The disease is characterized by ringlike spots on the skin, usually on the head, neck, shoulders, and rump, where the hair has come out and scabs have formed.

The treatment consists of removing the crust by washing with soap and water and using a stiff brush. The affected part should then be treated with tincture of iodine. The barn, stalls, etc., should be thoroughly cleaned, disinfected, and whitewashed to destroy the spores.

Parasitism.—Both internal and external parasites are widely distributed and cause large losses among cattle. The presence of external parasites can readily be observed by the dairyman and the proper treatment given. Internal parasites, on the other hand, are not visible, which makes their recognition and control more difficult.

An infestation of parasites may result in decreased growth or milk production, in a weakened condition which decreases the resistance to other diseases, and in death of heavily infested cattle, especially among the younger animals.

Symptoms commonly observed in cattle with gastro-intestinal parasites and Coccidia are unthrifty appearance, poor growth, and diarrhea, which may be intermittent. Symptoms vary with the species present and with the extent and duration of the infestation. Symptoms are generally more pronounced in young cattle. Since the symptoms are not diagnostic it is advisable if internal parasites are suspected to send a fecal sample to the state animal pathology laboratory for a diagnosis.

A correct diagnosis is also advisable from the standpoint of treatment, which varies with different kinds of internal parasites. The treatment commonly recommended for the gastro-intestinal parasites of cattle is 1 pint of a 1½ per cent solution of copper sulphate to yearling calves, and 1 quart of this solution to adult cattle. Undersized animals and those in poor condition should receive slightly less than the above dosage. Feed should be withheld for 24 hours prior to treatment, but not water.

Providing an abundance of good-quality feed is beneficial when used with copper sulphate in overcoming the harmful effects as well as eliminating gastro-intestinal parasites.

Lung worms are observed in cattle and may cause difficult breathing in addition to poor growth and an unthrifty appearance. Treatment consists of introducing a volatile substance such as chloroform into the lungs, which destroys the parasite.

Three or more species of Coccidia have cattle as their hosts. The most prominent symptom caused by coccidiosis is a diarrhea. A treatment for bovine coccidiosis consists of 7.5 grains of thymol given twice daily for a period of four days.

Lice.—Lice cause a great deal of trouble for the dairy farmer, especially among the calves, which are more susceptible to them than the grown animals. When calves are affected with lice they are often seen rubbing themselves, and if they are examined carefully the lice can be seen. However, one may not suspect lice. In such cases the calves fail to gain and are not thrifty. One should examine all such animals to ascertain the cause of the trouble.

The best treatment is to wash the affected animals with kerosene emulsions or tobacco sprays at intervals of several days until the lice are killed. A mixture of ½ pint of kerosene and 1 pound of lard can be applied in weather that is too cold to allow washing

or spraying. This treatment should be repeated as often as necessary.

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LECTURE XXX

DAIRY BARNS—CONSTRUCTION AND ARRANGEMENT

THE dairy barn, more than any other building on the farm, requires special and somewhat definite details of arrangement and construction. It is not the purpose of this lecture to discuss the strength of materials or the size of the timbers that should be used, but to give the details of size and construction of the floor plans, so as to enable the architect or builder who is unfamiliar with such structures to construct a barn that will meet the requirements of dairy animals.

There is no standard dairy barn. Dairymen do not agree as to the best shape and arrangement. However, various principles and requirements apply to all, and it is the purpose of this lecture to point out these important details. Before the plan is completed it must be viewed from various standpoints: from that of the bacteriologist, who wishes to know whether it is sanitary, clean, and safe for the production of milk; from that of the veterinarian, who is concerned with the health and comfort of the animals; and finally from that of the herdsman, who wants the barn to be constructed so that the cows will be comfortable and produce well, and at the same time to be made so convenient that his work can be done in the shortest time and with the least expenditure of energy.

For the architect, there is hardly any limit to the possibilities. With tall silos, large storage barns for hay and grain, and low barns for the cattle, pleasing combinations are possible. Simplicity is essential. It is the specialized dairy barn that will be discussed here, and not the general-purpose barn. Custom and city regulations are demanding more expensive barns for the production of special grades of milk.

Location.—The hilltop furnishes an ideal situation, but on account of cold winds and the occasional difficulty of securing suffi-

cient level ground for a group of buildings, it may not be so desirable from a practical standpoint. The difficulty of hauling hay and grain to a high location should also be considered. The side of a hill, especially one with a southern slope, is excellent for a small to medium-sized group. Whatever the location, the problem of drainage should be kept in mind. When a high grade of milk is to be

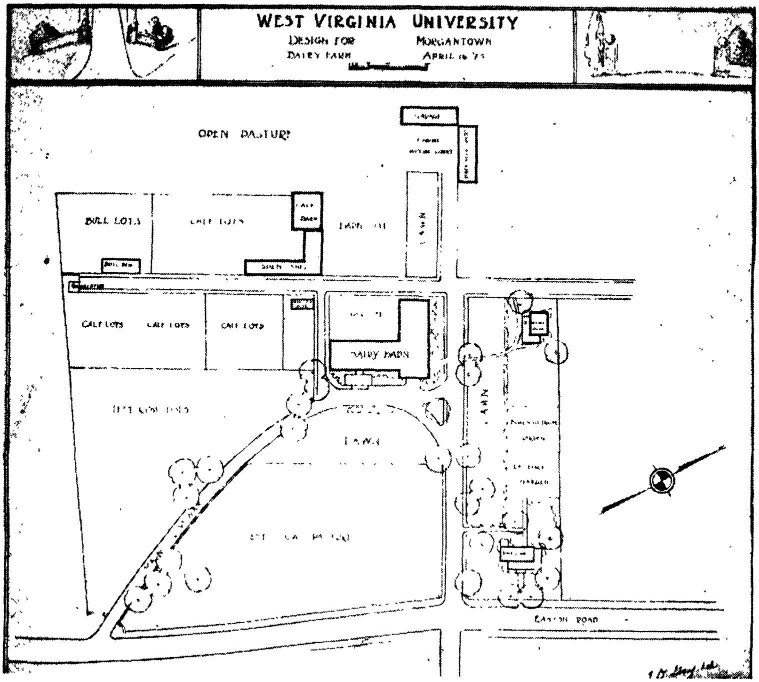

FIG. 82.—An attractive outlay for a dairy farm.

produced, a site should be selected that will permit of a good supply of running water in the barn.

Grouping.—In the arrangement of the buildings, convenience is an important consideration, though the feed barns and silos should not connect directly with the milking barn, for the former would admit dust and the latter odors to the barn. The large storage barns should not be so located that they will exclude light and sun from the animals. The cow barns should, if possible, have the long axis running north and south, or northeast and southwest, so

that the sunlight will reach both sides of the barn at some time during the day. The arrangement of the buildings should also be planned to protect the cow barns and the animals from winter winds. Young stock and dry cows should not be housed with the milking animals.

Round Barns.—The round barn, according to Fraser,[1] is one of the cheapest to construct. He has the following to say relative to that style.

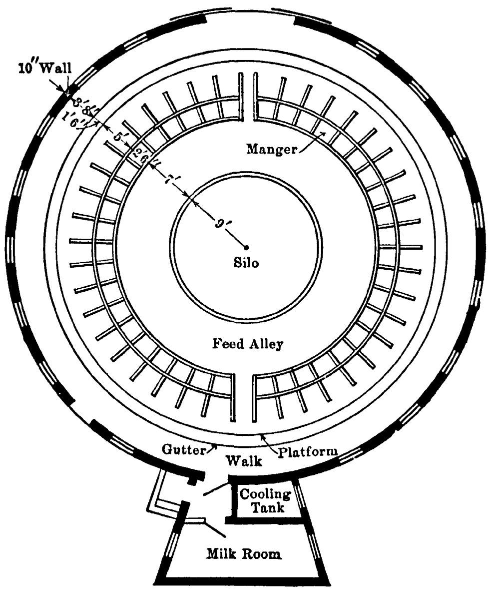

FIG. 83.—Floor plan of round barn for forty cows. (Ill. Exp. Sta.)

"The circular structure is stronger than the rectangular, and the latter requires 22 per cent more wall and foundation, to enclose the same space; and the cost of the material is from 34 to 58 per cent more for the rectangular than the round barn. The silo is usually placed in the center. The round barn can be built cheaper because lighter timber can be used. A large barn of this shape cannot be built to an advantage on account of light."

This saving in cost applies especially to frame buildings, and to the roof, which can be constructed of much lighter material than

[1] Ill. Exp. Sta. Circ. 230.

in the rectangular form of barn. On account of the scarcity of men who can construct the round barn, because of the difficulty of getting sufficient light into the center, and because of its limitation to one row of animals, it is not suitable for certain conditions.

Rectangular Barns.—In a barn of the rectangular type, a one-row arrangement can be used to advantage if the herd is small; but if a large number of cows are kept, two rows are preferable from the point of view of convenience, light, and expense. A four-row barn is objectionable because there must be many large posts to support the floor, and there is also difficulty in lighting and ventilating such a barn. When the herd is large enough to carry four rows,

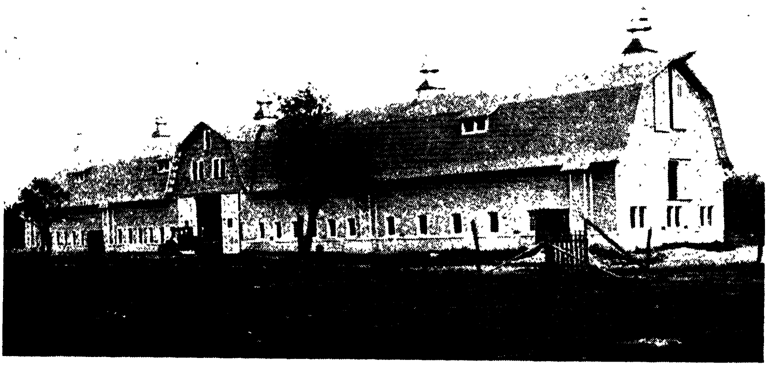

FIG. 84.—A large rectangular dairy barn.

it is better to build the barn longer or to build two separate cow barns. The expense would be somewhat greater, but it would be justified. The one-story cow barn is preferable for dairy animals because it is safer in case of fire, and, when it is properly connected with the hay and feed barn, and proper trucks and carriers are provided, the animals can be attended to almost as easily as in the two-story barn. In this type the hay barn can be built more cheaply by allowing the hay to go to the floor; this eliminates the heavy timber necessary in the construction when hay is stored on the second floor. When the cows are housed below the storage barn it is necessary to have the walls and timbers much heavier, and when the hay is allowed to go to the ground, a higher barn can be built

with much less expense; this saving can be used for the extra roofing of the one-story cow barn.

The Pen Barn with Separate Milking Room.—The pen barn system for dairy cows allows the cows to run loose in the barn except when they are being milked, when they are brought into a separate milking room. Such a barn requires very little equipment and necessitates less cleaning. The cows, if the barn is well bedded, will keep cleaner than when kept in stalls; and just as high-quality milk can be produced as when they are kept in ordinary barns. The amount of space required per cow is about the same as for other types of barn. The bedding need not be changed every day but

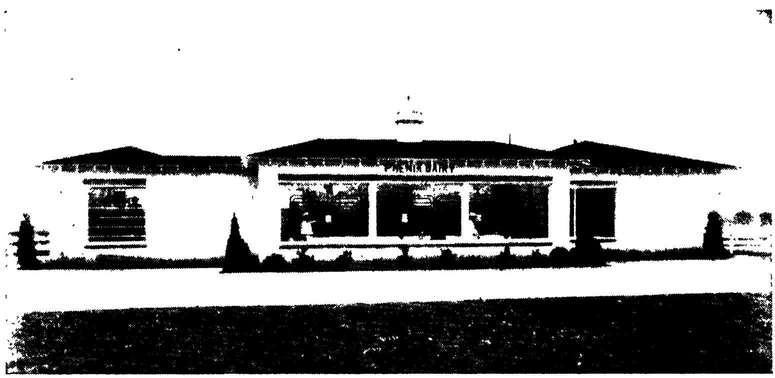

FIG. 85.—Milking parlor where the cows are milked by means of a "combine" milking machine.

only when it is most convenient. Feeding of hay and silage can be done in mangers or racks in the barn; but grain is usually fed at time of milking in the milking room.

The pen barn system requires considerably more bedding, and cows must be dehorned, otherwise some cows will prove troublesome. The milking room may sometimes be uncomfortable in cold weather unless it is small and well insulated.

The milking room should be near the barn so that the cows can be brought to it with a minimum of trouble. It is of various designs. A simple room with four to eight stalls, and so constructed that it can be easily cleaned, is all that is necessary. Many dairymen construct this room into a "milking parlor" where the cows are

milked, usually by machines behind glass windows, and where the process can be viewed by the public. The stalls are often raised so that the milker can operate the milking machine with a minimum of stooping. The cows are brought into the milking barn and placed in special stalls where they are fed their grain. Very often a "combine" milking machine is used, the milk being run through pipes to the milk room where it is cooled and often bottled without coming in contact with the air or other sources of contamination. The cows are often not stripped but the udders are manipulated so that most of the milk is obtained without stripping. When stripping is practiced the milk is usually fed to calves or otherwise disposed of; but

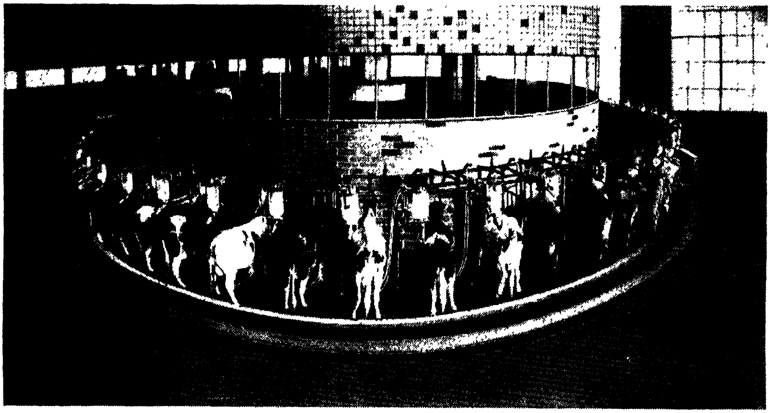

FIG. 86.—The "Rotolactor" at the Walker-Gordon Laboratories.

it is not put into the general supply. Such a system is used for advertising purposes.

A still more extensive layout is that of the "Rotolactor" operated by the Walker Gordon Laboratories in New Jersey. In this system the cows are placed on a circular rotating platform where they are first washed, and then milked by a machine. When the platform makes the circuit a cow is removed and another takes her place. The platform holds 50 animals so that there is a cow coming off and another going on all the time.

Such expensive outlays are not necessary on a small farm; the same advantages can be attained with less expensive equipment. Before a dairyman adopts any such system he should ascertain the

ruling of the health department in the city where he desires to sell his milk. Certain cities have milk ordinances that will not permit their use.

It is especially important, when a high-producing herd has been developed, to house the animals in a barn that is safe from fire. The open-shed system is being practiced in some localities, and from experiments conducted at the Pennsylvania Experiment Station[1] it is evident that dairy animals can be housed in open sheds during the winter. The results of these experiments indicate that the animals produce practically as well as in a good stable; that though the decrease in milk during a cold period was greater, the rate of increase during a warm period was also greater than in the closed barn. Slightly more feed was consumed by the cows in the open shed than by those kept in the modern stable.

Size.—For calculating the size of a barn for both feed and animals, some suggestions are offered herewith. The average cow does not consume more than 1 to 1½ tons of hay yearly. A ton of loose hay takes about 525 cubic feet of space, but when settled it requires only about 512 cubic feet. Straw takes a little more space by the ton, and about 1 ton is needed yearly for bedding for an animal. A ton of sawdust occupies 144 cubic feet of space, and 1½ tons are needed by a cow for a year. Baled shavings take 160 cubic feet per ton, and ½ to ¾ ton is required by a cow yearly. A cow eats from 3 to 5 tons of silage yearly, and a cubic foot of silage weighs 40 pounds. A storage capacity of 600 cubic feet is necessary for a whole year's supply of the grain feed of a cow.

In considering the size of the animal barns, 600 to 800 cubic feet of air space should be provided for each cow. If the cows are arranged in two rows, the cow barn should be from 34 to 36 feet wide if they face toward the outside, and at least 2 feet wider if they face the interior. In determining the length of the barn, 3 to 4 feet must be provided for each cow, the space depending upon the size of the cow. This does not make provision for alleys, which should be from 3 to 5 feet wide. Maternity pens should have 90 to 100 square feet of floor space, and individual calf pens from 12 to 15 square feet.

[1] Pa. Exp. Sta. Rept., 1913–1914.

There should be one box stall for every five or six cows, according to the cows in the herd and the degree of success attained in having the cows freshen at intervals throughout the year. Bull pens should be at least 12 by 12 feet. In the northern sections of the United States the height of the ceiling should rarely be over 8 or 9 feet, otherwise the cubic feet of air allowed for each cow will be too great to be maintained at the proper temperature; in the southern sections it may be 8 or more feet.

Ventilation.—It is important that proper change of air take place in the cow barn. A well-ventilated barn is essential. The whole problem of the proper ventilation of dairy barns depends upon

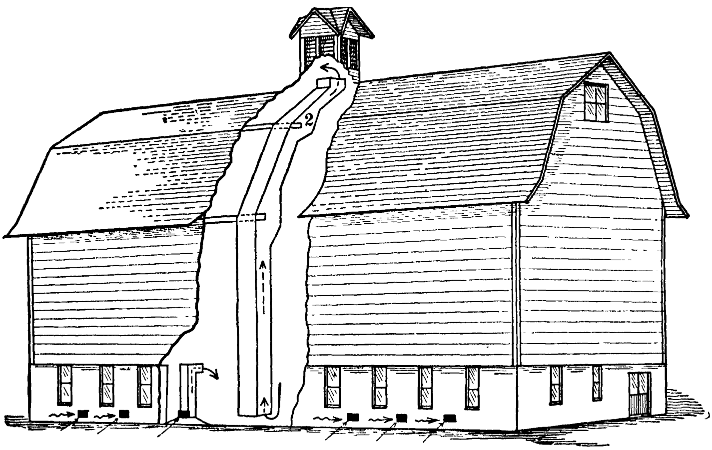

FIG. 87.—Showing details of the King ventilating system.

the factors of temperature and moisture. There is no difficulty in getting pure air into the barn during the summer, when windows and doors are constantly open; but it is a problem in winter to secure the proper change of air without making the barn too cold.

The air changes readily during the cold weather. The difficulty is to control it. The problem of ventilation would be simple, where artificial heat is applied to keep the barn warm, were it not for the difficulty of keeping the moisture in the air from condensing. The heat that radiates from the animal bodies is relied on to keep the room warm. If the space is not too great, and the walls are tight, sufficient heat is given off in this way to warm the air; but unless

there is an exchange of warm, moist air for cold, dry air, condensation will take place, and a damp, unhealthy stable will be the result.

The system of ventilation suggested by King, of Wisconsin,[1] or a slight modification of it, is the one now most generally used, although where electric current is available the fan type of ventilation is giving satisfaction and is replacing the gravity system. The King system is based upon the principle that warm air rises, while

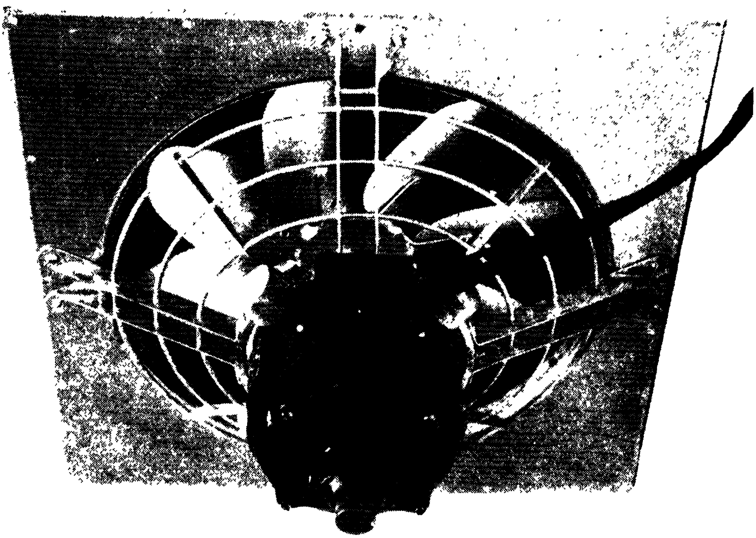

FIG. 88.—Fan type of ventilation. By means of an electric fan the foul air is removed from the stable.

the carbon dioxide or the foul air, which is heavier, settles to the floor. These conditions make circulation, which is essential to ventilation, possible. Cold, fresh air enters at the ceiling, and foul air is drawn off at or near the floor. In order to have this system work successfully, the walls, doors, and windows must be tight.

Theoretically, this idea is correct, but because of the heat given off by the cows, the air in the barn is constantly in motion, so that there is little difference in the composition of the air in different parts of the barn. This fact has led to the plan of drawing the air

[1] Wisc. Exp. Sta. Bul. 164.

off at the ceiling, in the center of the barn, and allowing the incoming air to enter at the walls near the ceiling. The heavy, cold air, as it enters through the small intakes, drops toward the floor; after it becomes warm the suction of the outtake carries it away. It is upon this idea that the modern system of ventilation is based. With this arrangement of intakes and outtakes, it is desirable to have numerous small openings for the admission of air, and few and large openings for its escape.

The square surface of the intakes should be slightly in excess of that of the outtakes. One square foot for every five or six cows should give ample ventilation. The outside opening of the intake should be at least 3 feet below the inside opening in order to prevent the warm air from flowing out. Theoretically, the outtake of the King system would draw off the heavier, impure air and less of the warm air when the outtake extends to or near the floor. This is true, although the difference between the two systems is slight, amounting to only a few degrees. It is inconvenient for the herdsman to have the large flues extending into the interior of the barn. The ventilating flues should be tight; if of metal they should be insulated to prevent condensation. The intake, if of metal, should have a board or some other non-conducting material between it and the inside plaster, if plaster is used. Unless this precaution is taken the cold air will cause condensation on the inside wall, and a wet streak will form along the wall at each intake.

It is well to have an excess of intakes and to provide them with dampers, so that those not needed can be closed. The outside openings should be screened to prevent birds or mice from entering. The outtake can be constructed from two thicknesses of boards, with the grain in opposite directions, and with one or two thicknesses of tar paper between. This flue should be as straight as possible and also as long as practicable.

The following method of calculating the size of the flue, devised by King,[1] will be of assistance for different conditions:

A 1000-pound cow requires 59 cubic feet of air a minute. Assuming that air travels through a flue at the rate of 300 feet a minute, the size of flue can be easily computed for any number of cows.

[1] Wisc. Exp. Sta. Bul. 164.

For example, we may assume that we wish to ventilate a barn for 50 cows. The formula will be

$$59 \text{ cubic feet} \times 50 = 2950 \text{ cubic feet of air}$$

$$\frac{2950}{300} = 9.83 \text{ square fet of outtake}$$

If two outtakes are used, they must contain 4.91 square feet, or 706 cubic inches each. A little more than this would be supplied in a flue 27 inches square.

Materials.—The selection of materials will be largely controlled by the locality. The frame barn is perhaps the most common type. It can be easily constructed and made attractive; but there is greater danger of fire from wood than from some other materials, and in many localities the expense is almost as great. A frame building can be made sanitary and comfortable for the animals.

In some parts of the United States hollow tile or concrete blocks can be secured almost as cheaply as wood; they are safer from fire, and, if provided with the proper air space, furnish a dry and satisfactory wall. They can be made dry and warm, and they are less expensive to keep in repair. Either of these materials offers excellent opportunities for stucco, which makes an attractive wall for farm buildings. Metal lath is sometimes used on a frame building for placing stucco on the outside and cement plaster on the inside. Stone or brick is satisfactory when plenty of air space is provided within the wall. A solid wall should not be used because of the condensation that is certain to take place on it.

Facing the Cows toward the Interior or the Outside.—There are advantages in both systems, and both are used. With the mangers together, work is saved in feeding; with the gutters together, the work of cleaning is lessened. More time is required to feed the cows than to clean out the stables.

With the system of overhead carriers there is perhaps no advantage to be gained in cleaning by facing the cows toward the outside. If the herd is large, however, and it is the practice to drive into the barn to get the manure, it is preferable to have them face toward the outside; even then, unless the herd is so large that a load, or nearly a load, of manure is obtained, the extra work of hitching up a team would hardly be justifiable. When the milking machine

is used there is some advantage in facing cattle outward, since with it cows on opposite sides of the alleys may be milked at the same time. The presumably greater danger of contamination among cows, because of their breathing into one another's faces, has been offered as an objection to facing them inward. This is perhaps not an important matter in a well-ventilated barn, especially if the barn is wide enough to permit the cows to be reasonably far apart. One of the disadvantages of facing the cows inward is that, unless the alley back of them is quite wide, the wall may become soiled. The

FIG. 89.—Stable with cows facing toward the center.

chief advantage of this position, however, besides convenience of feeding, is that the light comes where it is most needed, and the sun may shine into the gutter, drying it out and keeping it more sanitary.

Alleyways.—The width of the alleyways in the cow barn should be about 5 feet from the edge of the gutter to the edge of the wall when the cows face the interior, and about 4 feet from the manger to the wall when they face outward. The alleyway between the cows when they face inward should be at least 6 feet from manger to manger, and when they face outward about the same from gutter

to gutter, unless the system of carrying the manure out with the manure spreader is practiced. There should be a slight slope of about 1 inch in 4 feet to the gutter. The feed alleyways should be smooth, while the alleyways through which the cows walk should be made rough so that they will not slip. Cork or creosoted blocks are sometimes used for that purpose. If the surface is properly roughened there is little danger that the animals will slip, even on cement.

Platforms.—The platforms on which the cows stand are an important part of the barn construction. They should be of the proper

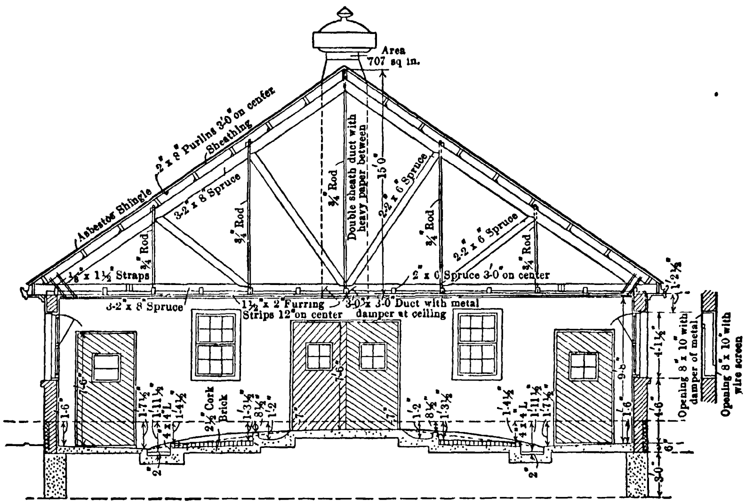

FIG. 90.—Cross-section of stable. Cows facing center.

length so that the manure will drop into the gutter and not on the platform. The length will depend upon the size of the cow. Adjustment can be made either by having the platforms longer at one end of the row than at the other, and by placing the larger animals at the longer end, or by the use of adjustable stanchions. Platforms of a suitable size for Jerseys are 4 feet 4 inches to 4 feet 7 inches; for Ayrshires and Guernseys, 4 feet 6 inches to 4 feet 10 inches; and for Holsteins, 4 feet 10 inches to 5 feet 6 inches. The platform should slope slightly toward the gutter. A slope of 1 inch in the total distance of the platform is sufficient.

A number of different materials are used for the floor of the platform. The dirt floor is objectionable because it is hard to keep clean, though it is comfortable for the animals. A further disadvantage is that it is soon cut up by the hoofs and the surface made irregular. Wood floors are not durable; they absorb liquids, and are difficult to keep clean. Concrete has been more generally used during recent years, but it is slippery and cold, especially if not properly underdrained, and is hard on the knees and hocks of the cows. The use of a coat of tar on a layer of tar paper, an inch or so below the upper surface of the concrete, practically cuts off the movement of the warmth of the animal below the point of insulation. The use of creosoted wood blocks or cork bricks for cow-barn platforms is increasing. Cows are not so likely to slip on them; they are not so cold; and there is less danger of injury to the udder, knees, and hocks. When properly laid they are sanitary and will last a long time.

Other compositions are being suggested for floors, such as a combination of cement and wood sawdust, also asphalt, although neither of these has come into much use. Some barns are provided with a plank surfacing that is put over the cement floor in the winter and taken up during the summer. Unless these floors are taken up and cleaned they become unsanitary.

Mangers and Curbs.—A concrete manger is sanitary and satisfactory. The bottom of the manger should be at least 1 inch above the platform on which the cow's front feet rest. The depth of the manger need not be over 6 inches, while a width of 26 to 36 inches is sufficient when the alleyway in front of the manger is on a level with the top of the manger. Some cows will push their feed out of mangers that are as wide as 4 feet and as high as 3 or 4 feet, but when the feeding platform is on a level with the top of the manger it is an easy matter to push the feed back into the manger. A disadvantage of having the manger built higher than the alleyway is that it is difficult to put the grain back when it has once been pushed out over the edge. An advantage, however, is that dirt and trash, which are carried in on the feet and trucks, do not get into the mangers.

The curb dividing the platform and manger and supporting the stanchions should be about 5 inches thick, and should have rounded

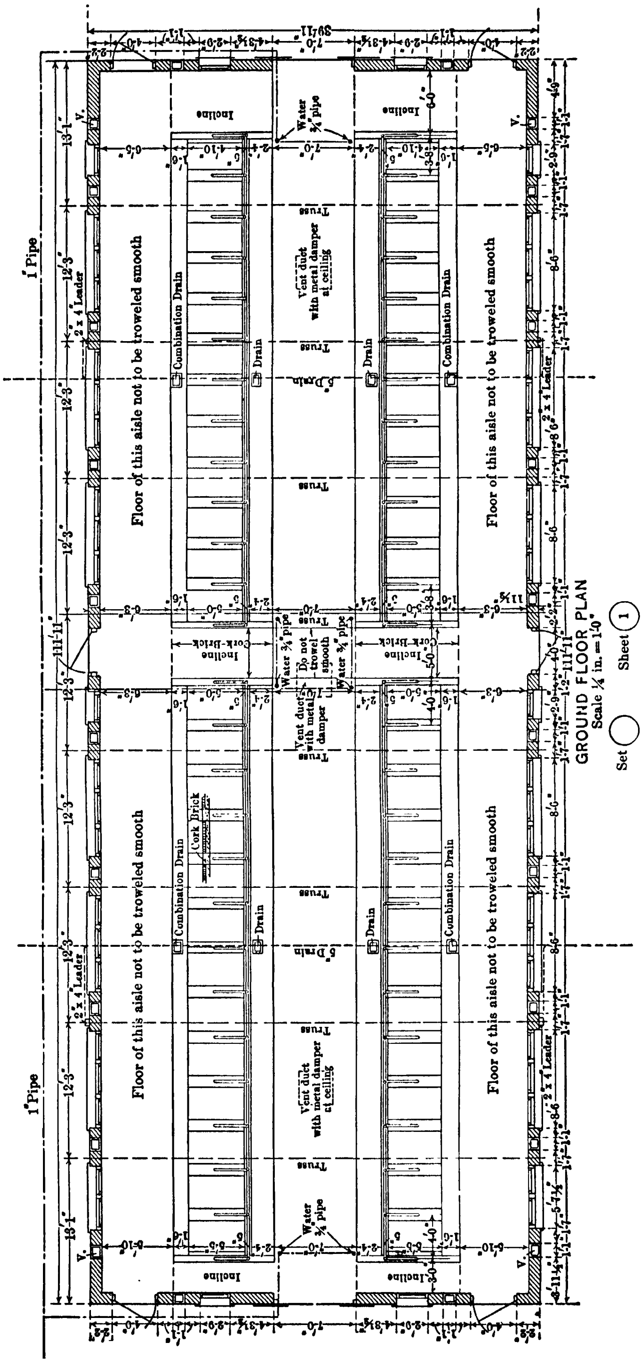

FIG. 91.—Ground floor plan of stable for fifty cows.

corners to protect the cows from injury. The height of the curb should not be over 7 inches at the point where the cow's neck extends over it. It may be higher at the sides. The plan of building a curb 11 or 12 inches high, and cutting out a semicircular piece to a depth of 5 or 6 inches, is satisfactory.

Partitions of some sort should be provided in the mangers, so that one animal cannot take the feed intended for her neighbor. Partitions that can be raised, making the manger continuous, are desirable from the standpoint of sanitation, but most of those that are on the market are not substantial enough. An iron rod simply run between the mangers, 12 or 14 inches from the bottom, will be sufficient to keep the animals from eating each other's grain, but it will not prevent the exchange of hay.

Wood, steel, and galvanized iron are also used for mangers and manger partitions, although many of the barns in which high grades of milk are being produced have the continuous concrete mangers already described. Some practical dairymen, however, believe that by the use of such mangers there is greater danger of spreading disease in the herd. Those who favor the concrete manger believe that because it can be thoroughly cleaned it is less likely to harbor disease germs. The advocates of the concrete system believe, further, that if contagious diseases are in the herd they are as likely to be transmitted in the yard or at watering places. The higher individual mangers, built of wood or metal, hold the feeds better, but are difficult to keep clean.

Windows.—There should be as many windows as the construction of the barn will permit. Windows cost no more than the same amount of wall, and the more light in the barn the better. The windows should be made flush with the inside wall so that there will be no ledges. They should extend almost to the ceiling, but should not be lower than 4 feet from the floor, when the cows face in, because of the danger of their being struck by the cows. A single sash with double panes of glass about ¼ inch apart adds little to the expense and very much to the value of the windows. If a single pane of glass is used, cold winter air on the outside condenses the moisture of the inside air and forms a heavy coating of ice on the glass. Not only does this coating exclude the light, but when

the sun melts the ice a wet wall is the result. With a double-glass window this condition is avoided.

The plan of fitting the upper sash into cheeks on either side and tipping it inward at the top admits air to the barn without a direct draft upon the cows. These windows are resorted to only when the weather is warm enough to admit more air than is furnished by the King system. In certain barns they are the only intakes used. This method of ventilation is known as the "Sheringham system." The windows are sometimes covered with muslin and the air and

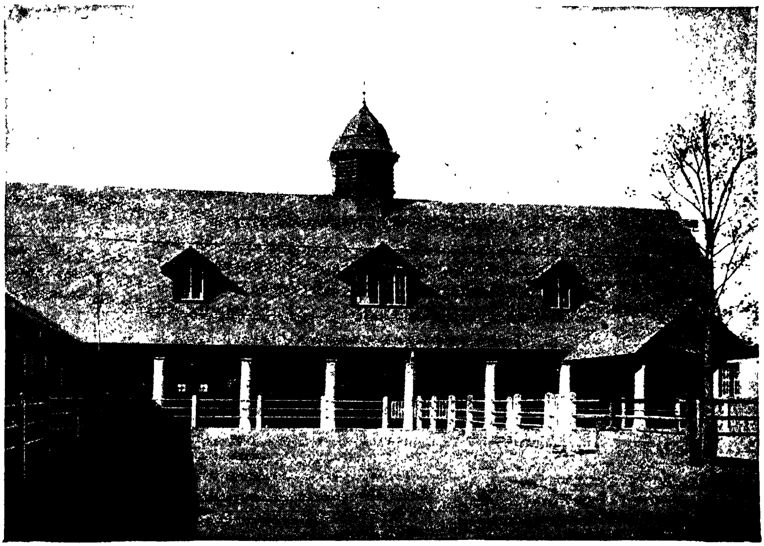

FIG. 92.—A clean dry yard made of crushed rocks.

light admitted in that way. The air readily passes through the muslin, but not as a draft. It should be kept in mind that this system makes a barn cold in northern climates, though where the King system is not used the muslin curtain is advantageous.

Drains.—The dairy barn should be provided with drains so that the floors and corners can be thoroughly washed with a large quantity of water. These drains, however, should be so constructed that they can be closed entirely, so that the liquid manure will not flow away; or they should be provided with a double opening so that the liquid manure can be caught and carried to a cistern, and when

the stable is being cleaned the washings can be run out into the general drains. The drains are best located in the gutters, mangers, and feed alleys. A $2\frac{1}{2}$ to 3-inch slope from the ends to the center of a fifteen-cow row is sufficient to carry off the liquid through the gutter.

Gutters.—There are a great many different suggestions for gutters. The main considerations are that they be deep enough to prevent the manure from piling up high and soiling the cow, and wide enough to keep the manure from dropping on the platform across the gutter. It seems desirable to have the edge of the gutter that is nearest the cows higher than the edge that borders the alley, for the cow easily steps up; in fact, she is likely to jump when the two platforms are on a level. The gutter should be at least 6 inches deep, and there is no objection to a depth of 9 inches nearest the cows, with a height 2 to 3 inches less on the alley side of the gutter. The gutter should not be too narrow, 18 to 22 inches being a desirable width.

Some gutters are made with round bottoms; others are sloped toward the back, in the belief that the liquid will be carried away better, and hence not soil the tail of the cow. The result is not always satisfactory, and such gutters are harder to clean.

Even a dirt floor should be provided with gutters, either of wood or of cement.

Steel gratings, made of bars about $\frac{1}{4}$ inch thick by 2 inches wide, placed on edge about 1 inch apart, are used to some extent in the gutter. It is believed that the cows can be kept clean by means of these; the manure and liquid are supposed to pass through to the gutter and to prevent the tail and hind quarters of the cow from getting soiled. Grating, however, is effective only if fine shavings or sawdust are used for bedding. Straw would keep the manure from falling through.

Some barns are constructed with platforms so short that the cows are obliged to stand on the grating. This has a tendency to cause sore feet. One thing to be said for the grating is that the cows can go in and out much more easily and safely than when they are obliged to cross an open gutter. The construction of the grating should be simple; it should be hinged throughout its entire width,

or contructed to be removed entirely, so that thorough cleaning is possible.

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LECTURE XXXI

DAIRY BARN EQUIPMENT

THE equipment of dairy barns is so far from being standardized that no attempt will be made to enumerate all the different devices that are on the market, or to discuss the advantages and disadvantages of different kinds of equipment. Some of the more common devices and their principles and uses will be discussed. Because of the constant changes in particular makes of equipment, trade terms will not be used in this discussion.

Ties for Dairy Animals.—The most common method of tying cows in dairy barns in this country is with stanchions. These are simple and sanitary. The cows can be tied easily and quickly with them, and can be kept in alignment with the platform, a condition which tends to keep the animals clean. The stanchions should be so constructed and arranged as to allow the cows the greatest possible freedom. There should be several links of chain at the bottom and top of the stanchion and sufficient room on both sides of it to permit the animal to move its head from side to side. Comfort is as important as proper alignment.

Another system of tying cows is one in which the stall is arranged so that when the cow is lying down she will be on a platform which is kept well bedded. When she gets up she must step back on account of the arrangement of the feed manger. In this way the bed is kept clean and the cow herself is kept free from dirt. The length of the stall can be changed to suit the size of individual cows. The cows are usually tied with a chain.

Still another method of tying the cows is to use two posts, one at each side of the cow, to which the cow is fastened by means of a ring and chains. This method permits considerable freedom, and at the same time keeps the cow in alignment. It is not so convenient, however, as the stanchions.

The single chain or rope method is sometimes used. The objection to this is that it permits the cows to move backward and forward to such an extent that it is impossible to keep the stall clean. Cows are sometimes kept in box stalls, but when this is done much more bedding and labor are required in order to keep them clean.

Partitions.—Although partitions between the cows are not necessary, they are desirable. Without them, one cow may occupy a part of the stall of another, making it impossible for the other to

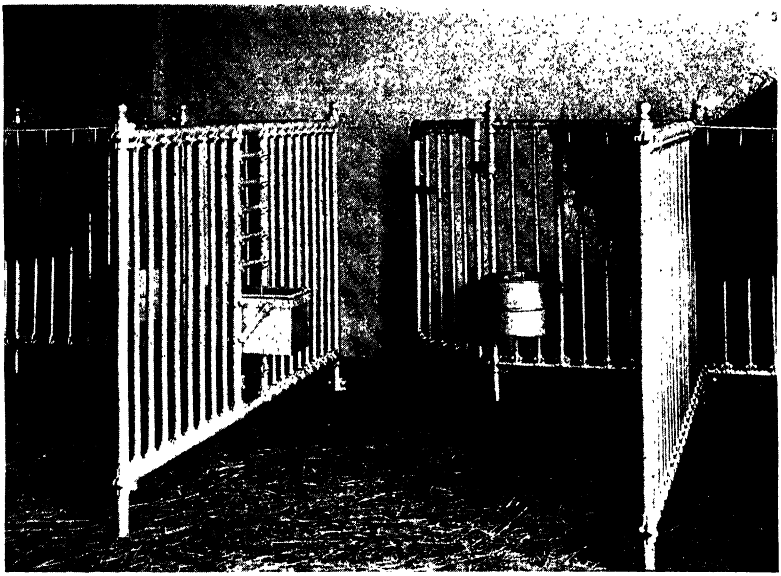

FIG. 93.—A sanitary box stall.

lie down; it is also easy, under these conditions, for one cow to trample on the udder or teats of the cow next to her, thus causing trouble.

The simple bent-rod partitions are satisfactory. For heifers or small cows, these partitions should be from 3 feet to 3 feet 6 inches apart; for the smaller breeds, such as the Guernseys, Jerseys, and Ayrshires, they may be from 3 feet 4 inches to 3 feet 8 inches; and for large animals, they may be as far apart as 4 feet.

Sometimes partitions are of solid wood, but they prevent proper

circulation of air, make the stable dark, and are very difficult to keep clean.

Feed Carts and Carriers.—The three-wheeled cart forms a simple device for the distribution of the grain. This should be provided with scales and a board to which the feed sheet may be attached so that the feeder can easily determine the amount of feed to be given to each cow in the herd.

Some barns are provided with an overhead track on which the

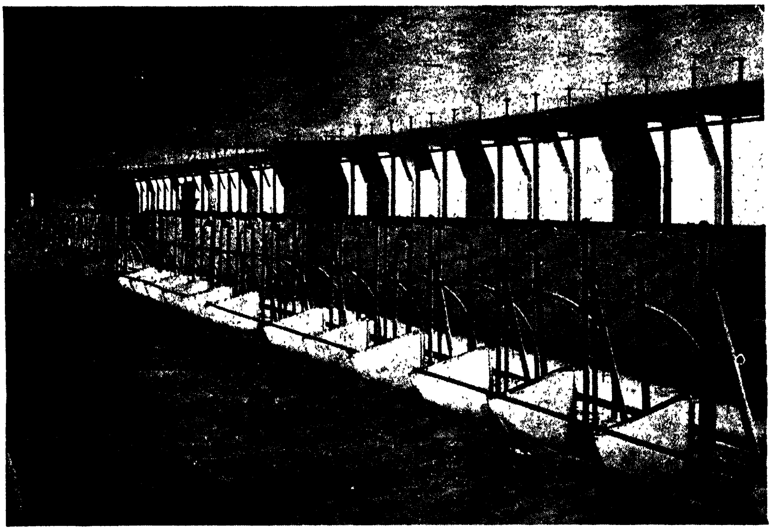

FIG. 94.—Manger partitions are handy, but not essential.

feed carrier is run. This is also a convenient method of feeding the grain.

The hay is usually slid along the floor to where it can be easily distributed, but when it is stored some distance from the stable special carriers must be provided. A low truck with the regular hay-rack body is very convenient. Hay is sometimes carried on a special platform suspended from a track.

The conveyors used for silage may be similar to those used for grain, but larger. Beet pulp may be fed from similar conveyors but they must be able to hold water, otherwise when the dried beet pulp is soaked the water will run out.

Litter Carriers.—In some barns, the cows are turned out each day and the manure is disposed of by driving through and loading it directly on the spreader. If the herd is large enough to supply a load of manure each day, this is a saving of labor, otherwise it will require more time to do this than to store the manure.

In a small herd, a wheelbarrow or small truck may be used. A smooth walk should be made leading to the manure pit, which should be located at least 50 feet from the barn.

The most common system in dairies of any size is the litter carrier, which runs on an overhead track. A large quantity can be moved more easily in this way than on a wheelbarrow. The manure may be dumped directly into a spreader or may be emptied into a

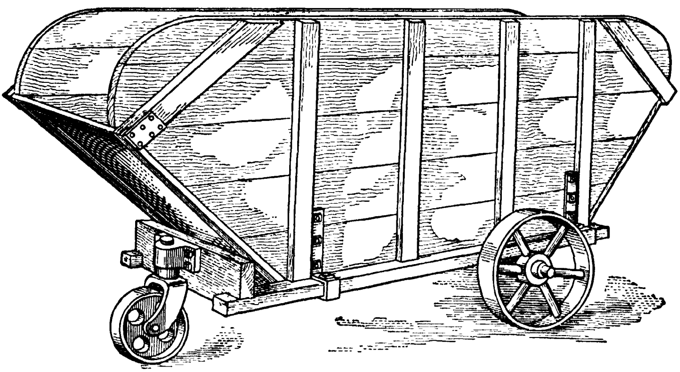

FIG. 95.—A handy feed cart.

manure pit where it may be stored until a convenient time for spreading.

For the rapid cleaning of barns there is a special device. The gutter is deep and provided with a grating, and by means of a special scraper and cable the contents are drawn to one end of the barn and loaded directly on to a wagon or put into a pit. The chief objection to the grating is that it is harder to keep clean than the open gutter. The special scraper for cleaning by machinery is a saving of time in cleaning the manure from a large barn. An engine or motor, however, must be kept in running order for each cleaning and, though the scrapers do remove practically all the manure, yet the deep gutter with a large surface requires additional cleaning when high-grade milk is produced.

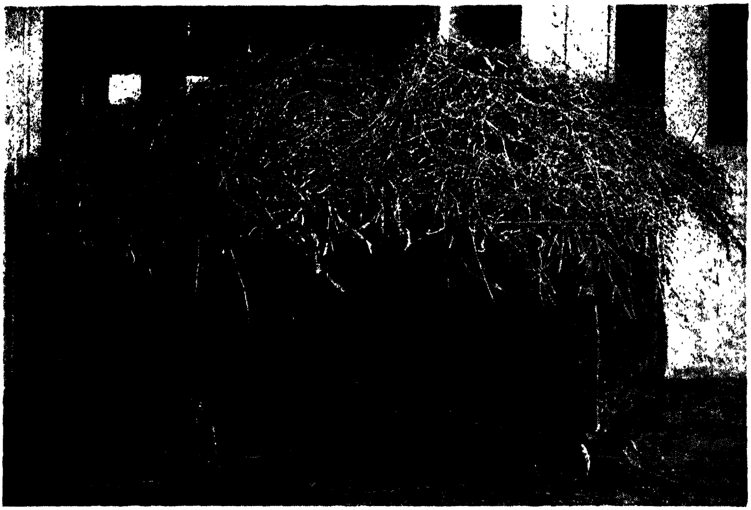

FIG. 96.—A hay wagon.

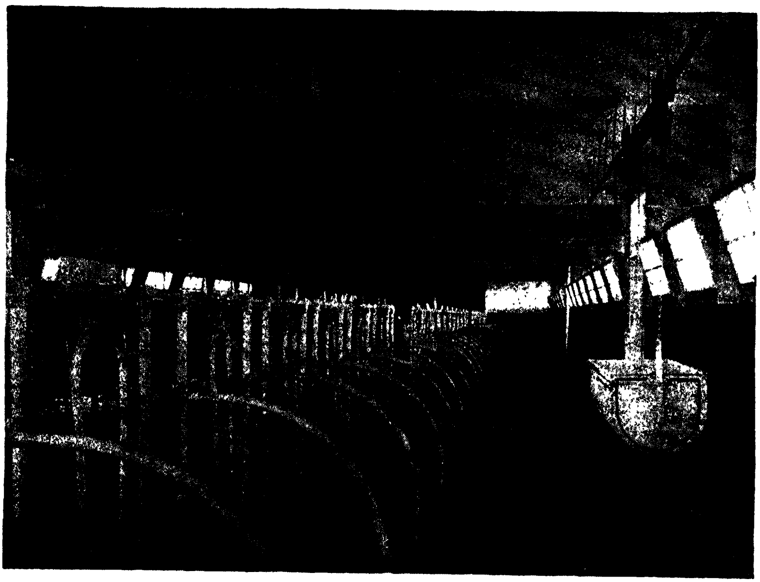

FIG. 97.—A litter carrier saves labor.

Watering Devices.—The system of turning cows out to drink once or twice a day is followed quite extensively. Some dairymen water once or twice a day by running water in a concrete manger in front of the cows. Cows, however, will produce a little more milk if they are given access to water at all times; also there is less opportunity for diseases to be transmitted from one to another when they have individual drinking cups. For these reasons, many dairies have individual watering cups which gives the cows access to fresh water at all times. There are two general systems of supplying

FIG. 98.—A watering cup arranged so that the cow can let the water in as she drinks.

water to watering cups. One is the gravity system, in which water is kept at a certain level in the cups by means of a large tank, provided with a float, at one end of the building; the other is the pressure system, in which the water is forced to the cups and let in by a valve, which the cows soon learn to operate. The latter is to be preferred where the water system permits. The objection to the gravity system is that when the water in the tank becomes low the water from the drinking cups flows back so that if any of the cows have an infectious disease it may spread throughout the entire herd

in this way. The same objection was found in the old-type pressure systems, but the modern drinking cup of this type has the valve at which the water enters the bowl above the normal level of water in the cup so that it is impossible for the water to flow back.

Care should be taken to keep the cups clean. Many cups now on the market give satisfaction.

Calf Pens.—Calf pens should be dry and well ventilated, but care should be taken that they are free from drafts. They should be provided with stanchions or ties, so that the calves may be tied

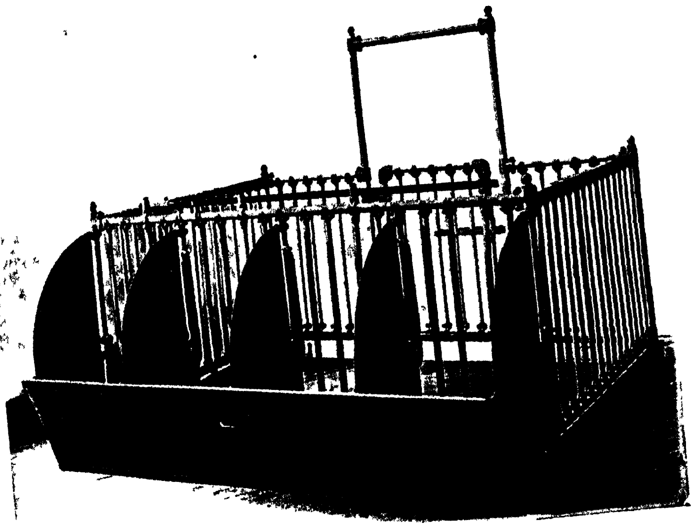

FIG. 99.—Manger partitions for calf pens

to prevent them from sucking one another after they have finished drinking their milk. In the summer calves are often allowed to run in an open lot. This should also be provided with stanchions where the calves may be tied after being fed. This makes it much more convenient to feed and at the same time insures every calf its required ration.

Milking Machines.—One of the most important problems on the dairy farm is that of labor, especially the labor involved in the milking. For this reason much effort has been made to perfect a

machine that will perform this operation satisfactorily. Mechanical devices for milking cows have been in process of invention and improvement for the past fifty years, but it is only within the past twenty-five years that they have appeared on the market in forms reliable and efficient enough to warrant their serious consideration for ordinary farm or commercial use.

Many makes of milking machines are on the market today, but practically all employ the vacuum principle; a few use both the vacuum and pressure. Milking machines differ principally in contruction. All models have pulsators which are operated by air pressure.

The principal advantage of a milking machine is that it saves labor. At the Kentucky Station [1] it was found that the average time required to milk a cow with a machine was 3.99 minutes. The machine did not draw the milk from the cow much faster than a fast hand milker, but one man could operate two or three units at a time. It required two men with four units 43.3 minutes to feed, milk, strip, and weigh the milk from twenty-eight cows; the same operations, when the milking was done by hand, required 1 hour and 20 minutes. The average time required to milk a cow at the Texas Station [2] with a milking machine was 4.643 minutes, and by hand it was 7.269 minutes. The care of the machine required on the average 23.7 minutes per day.

There seems to be some disagreement as to whether milking machines will maintain the milk flow as well as hand milking. This depends largely upon the kind of hand milkers who are available and also upon the method of operating the milking machine. The Kentucky Station tabulated the milk yield from the thirty days preceding and the thirty days after the beginning of the use of the milkers, and found that there was no appreciable or permanent decrease in milk production due to their use. The New York Experiment Station [3] found that the milking machine did not maintain milk production as well as hand milking, but concluded that this was at least partially due to the method of operation. The Danish Re-

[1] Ky. Exp. Sta. Bul. 186.
[2] Tex. Exp. Sta. Circ. 30.
[3] N. Y. Exp. Sta. Bul. 654.

search Laboratories [1] also found that hand milking was to be preferred if the greatest milk yield is to be obtained. They state that, under conditions where good hand milking is difficult to obtain, the milking machine may be a solution to the problem.

FIG. 100.—Breeding Rack. Dimensions, floor planks 9 feet long, front posts 4 feet, and rear posts 1½ feet. One and one-half feet between floor planks in front and 2 feet in rear.

With regard to the effect of the milking machine on the quality of the milk, it has been found that, when the machine is thoroughly sterilized and kept in proper condition, there is practically no difference in the number of bacteria in the hand-drawn and machine-drawn milk. Experiments seem to indicate also that the machines as

[1] Hansen's Dairy Bul. 20:25.

now constructed have no bad effect upon the udder or the health of the cows, provided the teats and udders are normal at the beginning. Although it does not seem to harm the cow if she is not stripped after the milking machine, nevertheless, a little more milk will be obtained if stripping is practiced. Usually it will pay to strip the cows.

FIG. 101.—Stocks. Dimensions, total length 9 feet, height 6 feet. Width inside 2 feet 4 inches, and 2 feet 8 inches from stanchion to floor ring.

The success of a milking machine depends largely upon the operator. With a careful operator—one who takes care of all details and watches his machine closely—it is fairly certain that the machine will give perfect satisfaction. With the careless operator trouble will always be experienced. The milking machine is simply a machine and must be treated as such.

Breeding Rack.—The breeding rack is used for two purposes:

1. For the breeding of small cows or heifers by a large bull, or of large cows by a small bull.

2. For the breeding of animals that do not readily stand.

Occasionally, also, a bull will serve to better advantage when a rack is used. The breeding rack should probably be used more than it is, but because of the inconvenience of adjusting it for each animal, and because of the trouble of bringing both animals to it, most herdsmen do not usually use it until it is absolutely necessary. The stanchion of the rack should be adjusted so that a small animal can be held back and a large animal allowed to go forward. It is well to have the sloping part on which the bull's front feet rest provided with cross strips, as well as a strip along the outer side to keep the bull's feet from sliding off. The dimensions and method of construction are shown in Fig. 100.

Stocks.—Stocks are strongly made crates in which animals can be held successfully during the trimming of hoofs or dehorning, or while other operations are being performed, when it is necessary to have the animal under full control. Stocks are especially useful for the handling of bulls. They should be constructed of good material and well bolted together. They should be made adjustable so that they can be used to hold animals of different sizes. This can be done by having several slots for the timber inserted at the back to hold the animal in place, and also for the stanchion. It is sometimes difficult to get animals into a stock. This is especially true of bulls. The difficulty can be overcome by going slowly and, if necessary, tying the obstinate one for a little while at the entrance to the stock. Figure 101 shows the construction and dimensions of a satisfactory cattle stock.

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7. Tests of a Mechanical Cow Milker, Mairs, Pa. Exp. Sta. Bul. 85.
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9. Experiments with the Sharples Mechanical Milker, Hooper and Nutter, Ky. Exp. Sta. Bul. 186.
10. The Efficiency, Economy, and Physiological Effect of Milking Machinery, Woll and Humphrey, Wisc. Res. Bul. 3.
11. Milking Machines, Haecker and Little, Nebr. Exp. Sta. Bul. 108.
12. Important Factors Affecting Milking Machines, Larsen, S. D. Exp. Sta. Bul. 166.
13. Sanitary Cow Stall, Ocock, Wisc. Exp. Sta. Bul. 185.
14. Some Unessential Dairy Refinements, Hall, Geneva (N. Y.) Exp. Sta. Bul. 365.
15. The Use of Water Bowls in the Dairy Barn, Cannon, Hansen, and O'Neal, Iowa Exp. Sta. Bul. 292.
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LECTURE XXXII

THE PRODUCTION OF HIGH-GRADE MILK

WITH the proper barn and equipment, as described in previous lectures, it should not be a difficult task to produce high-grade milk. The equipment, however, is not all that must be considered in this connection. Proper methods must also be followed if the best results are to be obtained. In fact, high-grade milk may be produced in very ordinary barns and with mediocre equipment, if the methods are good. In order to produce clean, high-grade milk, the dairyman must understand what constitutes cleanliness and be willing to watch all details which are necessary for the production of such milk.

Milk is easily contaminated with dirt, bacteria, and odors. When the proper temperature is maintained it furnishes an excellent medium for the growth of bacteria. Great care is necessary in the production and handling of milk as a food product, in order to put it in the hands of the consumer in satisfactory condition.

INSPECTION OF MILK

There are two general methods of inspection to determine whether milk is being produced in the proper manner. One is to examine the milk itself, as it reaches the market, by means of acid tests, reductase tests, sediment tests, or bacteria counts. Sometimes two or more of these tests are combined.

The second method of inspection consists of an examination of the conditions on the farm. Such things as the health of the cows, the condition of the stable, and the methods used are taken into consideration. Many cities employ a combination of the two systems.

Examination of the Milk.—Milk that contains considerable sediment, as indicated by the sediment tester, shows very plainly that it has been produced under unclean conditions. The acid test and the reductase test may indicate the age of the milk rather than its cleanliness. The presence of a large number of bacteria

may be due to the age of the milk or to the number of bacteria in the milk when it was drawn from the cow. A small number of bacteria in raw milk, however, indicates that the milk has been produced under clean conditions. The number of bacteria found in a sample of raw milk depends upon three factors: the number of bacteria in the udder at the time the milk was drawn; the number that have gained access to the milk since it was drawn; and the amount of growth or increase that has taken place previous to the examination. If milk is properly produced and carefully handled it should contain only a few bacteria, even though it is held for some time before being put on the market. The ordinary method of counting the bacteria in milk is the plate method. This method, however, is slow and takes considerable equipment. A direct microscopic method has been devised whereby a direct count may be made by the use of the microscope [1] in a very short time.

Examination of the Conditions at the Farm.—When the conditions at the farm are examined they are usually rated by means of a score card. Of the many score cards that have been used, the one devised by Pearson and modified by the American Dairy Science Association has been used most extensively. This score card is shown on the following page.

It will be noted that 40 points have been given for equipment and 60 points for methods. The different values are merely arbitrary, and the score card is chiefly useful in indicating the various points to be considered in the production of high-grade milk. In this way it not only serves as a guide for the inspector but also helps the dairyman to know how to equip his stable and what methods to follow in order to produce good, clean milk.

Producing High-grade Milk

Milk, to be high grade, must be clean and of good flavor, and have only a few bacteria, none of which must be harmful. In order to produce such milk, very careful methods have been devised. These methods do not require elaborate or expensive equipment but they do require the greatest care and cleanliness.

[1] N. Y. (Geneva) Exp. Sta. Tech. Bul. 49.

Healthy Cows.—Milk should be produced from cows known to be free from disease. As stated in a previous lecture, tuberculosis in dairy cows, especially when the udder is affected, may be the cause of tuberculosis in humans; and undulant fever may be caused by the consumption of milk from cows with Bang's disease. Cows should be tested for tuberculosis and Bang's disease at least once a year, and if the disease is found the test should be made at least twice a year. All reacting animals should be removed from the herd, and the stables and premises thoroughly disinfected.

FIG. 102.—Clean, healthy cows are the first essential in clean milk production.

Milk that is in any way abnormal should be discarded. Ropy milk, slimy milk, or milk which comes from an animal that appears sick or out of condition should not be used for human consumption. As a general rule, milk from a cow two weeks before calving or five days after calving should not be used. Only milk from healthy, normal cows should be used.

Clean Cows.—Much of the dirt and dust that gets into the milk comes from the cow's flanks, udder, or belly during milking time. For this reason the cows should be cleaned before they are milked.

The amount of labor required to keep a cow clean is lessened by having the platform of the right length, by using sufficient bedding, and by keeping the hair clipped from the udder, flanks, and part of the belly. Long hairs that drop carry with them large numbers of bacteria. Dust also is removed with greater difficulty if long hair is allowed to grow on the parts mentioned. When kept in the barn the cows should be given at least one complete grooming daily. This should be done some time before milking so that there will be time for the dust to settle.

It is also desirable to wipe the udder and flank with a clean, damp cloth immediately before milking. This materially reduces the bacteria count, as shown by Table LXXXV.[1]

TABLE LXXXV

EFFECT OF BRUSHING, WASHING, AND DRYING OF COW'S UDDER AND FLANKS ON BACTERIA COUNT

Housing of Cows	Condition of Cows	Number of Experiments	Average Count per Plate
Summer—all cows out	Untouched	7	440
Summer—all cows out	Udder and flanks washed and brushed	3	170
Winter—cows indoors	Untouched	3	4752
Winter—cows indoors	Udder and flanks brushed	3	1752
Winter—cows indoors	Udder and flanks brushed, washed and left moist	6	230
Winter—cows indoors	Udder and flanks brushed, washed and dried	3	440

Milk always contains some bacteria when drawn from the cow. The number of bacteria found in the udders of different cows varies considerably. In studies by Sherman [2] on udder flora, it was found that certain animals produced milk containing not more than 300 or 400 bacteria per cubic centimeter, whereas the milk of others did not go below twenty or more thousand. This may possibly be caused by the fact that the opening of some teats is larger than that

[1] Rept. on Milk Contamination, 1908, Orr.

[2] Unpublished data, Pa. Exp. Sta.

of others, or that the sphincter muscle of the teats closes imperfectly, allowing a greater number of bacteria to enter the udder. Udder trouble, such as garget, also results in more bacteria being given off in the milk. Some cows may have chronic udder trouble which is not generally noticeable, but which causes them to give off large numbers of bacteria. Whatever the cause, it is necessary in the production of the highest grade of milk to make a study of the individual animals and to eliminate those that constantly produce milk with many bacteria. As there are slightly more bacteria in the milk first drawn than in that drawn later, it is the practice of some to discard the first few streams from each teat.

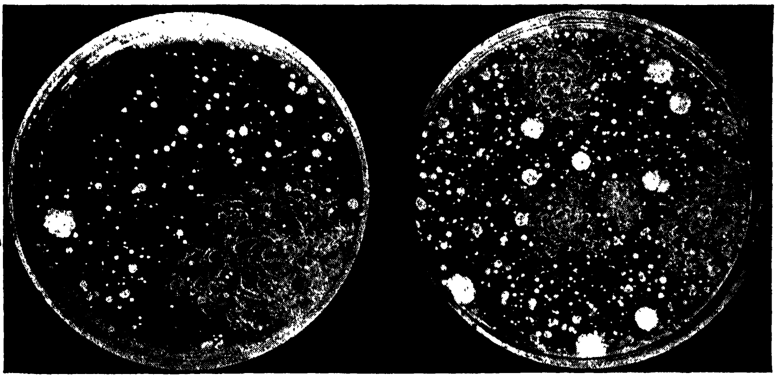

FIG. 103.—Plates exposed to the air of a stable. The plate on the left was exposed five minutes and the one on the right for ten minutes. (*Trout.*)

Clean Stables.—Whenever possible, the barn should be located on high ground with good natural drainage and at a good distance from poultry houses, hog pens, manure piles, or other surroundings which might pollute the barn air and furnish breeding grounds for flies and bacteria.

The floor of the barn should be non-absorbent and smooth so that it can be easily cleaned. Drains should be provided so that the floors and walls can be washed. The stalls and mangers should be such that they offer the least surface for collecting dust and dirt and the least obstruction to the circulation of air. Good ventilation should be provided so that the air will always be kept pure and clean, both for the health of the cows and to avoid the effect of

impure air on the milk. Too much light cannot be provided; bacteria do not live well in bright light, especially sunlight. The light not only shows the presence of the dirt but also helps to keep the barn in a sweet condition.

The stable air should be kept clean. Dust carries bacteria, and hence it is necessary in the production of clean milk to have the barn as free from dust as possible. Feeds containing dust should not be fed for some time before milking nor should dusty bedding be used. Figures 103 and 104 [1] show the effect of dust in the stable air. Figure 103 shows agar plates exposed to the air of a stable for five and ten

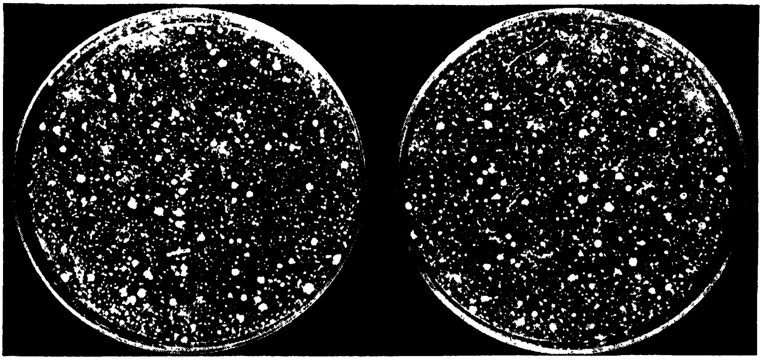

FIG. 104.—Plates exposed to the air of the same stable as those in Fig 103, but just after they had been put down the chute. The large number of colonies of bacteria indicate the presence of enormous numbers of bacteria on hay dust. The plate on the left was exposed five minutes and the one on the right ten minutes. (*Trout.*)

minutes, while Fig. 104 shows agar plates exposed to the air of the same stable for five and ten minutes just after hay had been put down the chute. Studies by several experimenters [2] seem to indicate that the methods of management and air control as generally practiced in well-managed dairies have less influence upon the number of bacteria contained in the milk than was formerly believed.

Care should be taken in the feeding of cows to protect the milk from contamination, both while it is being drawn and after it has been drawn. Certain feeds impart a good flavor to milk, and others an objectionable flavor. None of the feeds with strong odors, such

[1] W. Va. Exp. Sta. Circ. 43.

[2] Thesis, Etters, Pa. Exp. Sta.; N. Y. (Geneva) Exp. Sta. Bul. 409.

FIG. 105.—Clean healthy milkers are also essential for clean milk production.

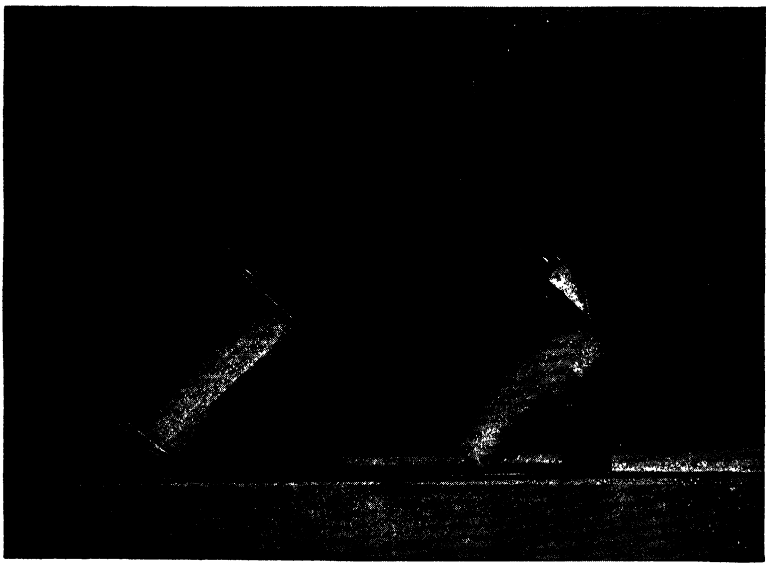

FIG. 106.—A small top milk pail keeps much dirt out of the milk.

as turnips or silage, should be fed immediately before or during milking.

Clean Milker.—The methods of the milker are important in the production of clean milk. A man who is clean in his milking operations can produce high-grade milk in almost any barn, while the careless milker cannot produce good milk under the best barn conditions.

The milker should be healthy, and should avoid exposure to communicable diseases. When a high-grade milk is being produced, especially if it is not pasteurized, it is desirable that the men doing the milking be examined for evidence of septic sore throat, typhoid, or other disease germs, as often healthy people may be "carriers" of certain disease germs.

The milker should take especial care of his hands and should always milk with clean dry hands. If the teats are hard and dry, and it seems necessary to moisten them, a small quantity of vaseline may be applied after they have been washed. The milking should be done quickly and thoroughly. Clean clothes should always be worn by milkers.

Small-top Milk Pails.—A large part of the dirt in milk falls from the body of the cow into the pail at milking time; hence it is easy to see the advantage of a small-top milk pail. The use of such a pail results in a cleaner milk and a lower bacteria count, because it keeps much of the dirt from getting into the milk. In a study of the effect of a covered pail in a stable where but little attention is given to cleanliness, the Connecticut Experiment Station [1] obtained the results shown in Table LXXXVI.

A small-top pail may seem awkward at first, but with a little practice one will find that it can be very satisfactory. Some health authorities object to the use of this type of pail because some producers neglect to cleanse the pail thoroughly under the cover.

Handling the Milk.—The milk should be removed to the dairy house immediately after it is drawn. Contamination will take place if it is left in the barn. Milk readily absorbs the odors of the stable.

The milk should then be strained into cans. If the cows are carefully milked the straining should not be necessary as it is impos-

[1] Storrs (Conn.) Exp. Sta. Bul. 48.

TABLE LXXXVI

EFFECT OF COVERED PAIL IN STABLE WHERE BUT LITTLE CARE IS GIVEN TO CLEANLINESS

A—Open Pail

Number of Experiment	Total Bacteria	Acid Bacteria	Liquefying Bacteria
1	811,900	761,660	23,790
2	9,100,000	9,087,900	4,160
3	3,113,000	2,025,000	26,660
4	3,025,000	314,600	30,000
5	4,470,000	2,443,000	26,660
6	115,400	21,040	10,000
Average.......	3,439,200	2,442,200	18,550

B—Pail with Cover

1	19,790	13,330	0
2	219,160	189,800	0
3	64,580	27,000	14,580
4	90,000	32,000	4,000
5	220,800	81,600	15,830
6	7,250	3,500	166
Average.......	103,600	57,800	5,760

sible to strain bacteria out of milk. However, it is usually desirable to strain the milk in order to remove any hairs or particles of bedding or feed which may have happened to get into it. The strainer should be of the cotton-pad type, and a clean pad should be used at each milking. This will remove more of the sediment than the wire gauze or cloth type of strainer.

Cooling the Milk.—Proper cooling is one of the essential features in the production of high-grade milk. Even though milk has been carefully produced, it will contain a large number of bacteria when it reaches the consumer unless it is properly cooled and held at a low temperature until it is delivered. It is impossible to produce milk without some bacteria; the point to observe is to prevent the multiplication of the bacteria that have already gained access.

If the temperature is held below 50° F. the increase in the number of bacteria will be very slow, whereas a temperature much above

FIG. 107.—A milk house for a small dairy.

50° F. will cause them to increase rapidly. Table LXXXVII[1] shows the importance of keeping milk cool:

TABLE LXXXVII

EFFECTS OF VARYING TEMPERATURES UPON THE BACTERIA GROWTH IN MILK

Temperature Maintained for 12 Hours, °F.	Bacteria per cc. at End of 12 Hours
40	4,000
47	9,000
50	18,000
54.5	38,000
60	453,000
70	8,800,000
80	55,300,000

[1] N. Y. Dept. Agr. Circ. 10.

Utensils.—It is important that the dairy utensils be constructed with smooth, filled joints and corners, so that it will be easy to keep them in good condition. Rusty tinware should not be used. One of the most common sources of contamination of milk is the utensils. In one experiment, milk drawn into sterilized pails had an average bacterial count of only 6306 per cubic centimeter, while

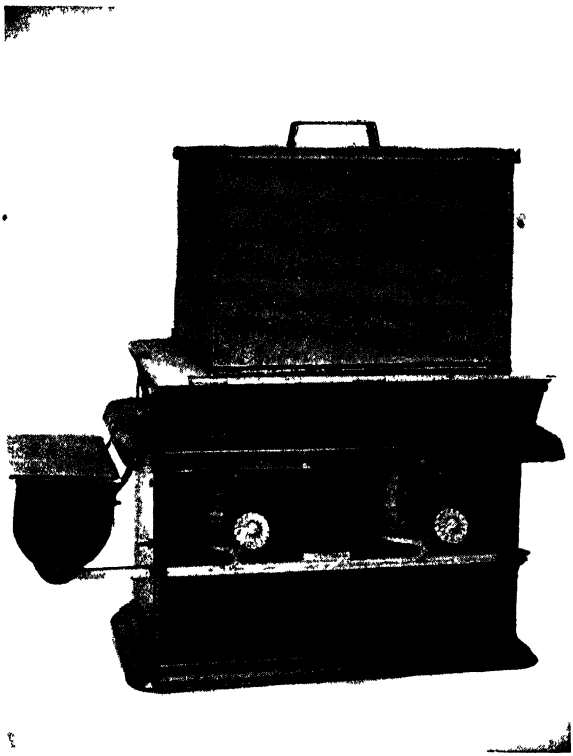

FIG 108—A cheap sterilizer for a small dairy.

samples from a pail which had not been sterilized contained, on an average, 73,308 bacteria per cubic centimenter. Even when the utensils are well washed and presumably well cleaned, bacteria may exist and increase very rapidly in them.

Utensils should, therefore, be thoroughly washed and then sterilized. Sterilization is best done by exposing the utensils to steam for

several minutes in a home-made sterilizer or by placing them in a sterilizer under pressure or by using a chlorine solution.

Utensils should first be washed with lukewarm water, then with hot water and washing powder, preferably an alkaline powder, not soap. They should then be rinsed and sterilized. The proper sterilization of utensils is, no doubt, the most important single factor in the production of milk with a low bacterial count. The effect of sterilization of dairy utensils is shown in Table LXXXVIII.[1]

TABLE LXXXVIII

EFFECT OF STERILIZATION OF DAIRY UTENSILS UPON PRODUCTION OF CLEAN MILK

Sample Number	Bacteria per cc. in Milk When Utensils Were:		Sample Number	Bacteria per cc. in Milk When Utensils Were:	
	Sterilized	Not Sterilized		Sterilized	Not Sterilized
1	9,000	45,000	9	35,000	200,000
2	20,000	60,000	10	32,000	340,000
3	11,000	150,000	11	240,000	750,000
4	16,000	450,000	12	2,500	350,000
5	2,500	200,000	13	3,800	750,000
6	23,000	130,000	14	2,600	400,000
7	2,400	160,000	15	12,500	600,000
8	45,000	175,000	16	2,800	550,000

These comparisons were not made on the same day, but the conditions were maintained as nearly uniform as possible throughout the test.

Sterilizing Milking Machines.—Clean milk can be produced by the use of a milking machine if the parts are properly sterilized after each milking. The machine should first be rinsed in cold water and then washed thoroughly, just as the other utensils are, after which it should be sterilized.

There are three common methods of sterilizing milking-machine parts, namely: heat, chloride of lime, and a mixture of a brine and

[1] U.S.D.A. Bul. 642.

chloride of lime. Burgwald[1] found that, of these three methods, sterilization by heat gave more uniform and appreciably lower bacterial counts than the other two methods. There was practically no difference in the results obtained by the chloride of lime method and the brine and chloride of lime method during the colder weather. Neither gave as good results in warm weather as in cold weather, but brine and chloride of lime gave a much better result than did the chloride of lime alone.

Heating the rubber in a sterilizer caused it to deteriorate very rapidly; but putting the rubber parts in water[2] at a temperature of 160 to 167° F. for twenty to thirty-five minutes, and then removing them to a refrigerator or placing them in a weak chloride solution between milkings, not only kept the rubber from deteriorating, but resulted in a low bacterial count. Care must be taken at all times if high-grade milk is to be produced with a milking machine.

Delivery and Transportation.—The condition of the milk on its arrival at the place of its disposal governs its acceptance or rejection. No matter how much care may be taken on the farm to produce good milk, poor delivery methods may result in unsatisfactory milk at the delivery point. Milk, once cooled, should be maintained at a low temperature until delivered, but should not be permitted to freeze. Milk for human consumption should be sent to market every day.

When milk is transported from the farm the cans should be covered, either by blankets or by individual can covers. Milk left on the roadside platform should be protected from heat, dust, and freezing.

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[1] Jour. Agr. Res. 31, No. 2.
[2] Jour. Agr. Res. 34, No. 1.

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LECTURE XXXIII

METHODS OF MARKETING MILK

THE marketing of the products of the dairy is, from the financial standpoint, of the greatest importance. In some localities only one method of disposing of the milk is available; the producer must sell it to a creamery, a cheese factory, a condensery, or a city milk plant. Again, none of these may be available, and he must, because of his location, manufacture his milk into butter or separate the cream, which he can deliver at less frequent intervals, and carry some distance to the market. Usually, however, there is more than one market for the product.

It is not the purpose in this lecture to discuss the best method of disposing of the milk, but rather to point out a method of calculating the relative values of the various ways of disposing of it. The dairyman should be alert to these possibilities, as often greater returns can be derived from selling in one form than in another. A dairyman often sells his product in one form at a much lower price than he could obtain for it in another, because he is unfamiliar with the methods of calculating the relative values of the different forms of selling. No attempt will be made in this lecture to discuss every possible method of selling.

Selling Whole Milk.—Perhaps the greater part of the milk of this country, especially that of the east, is sold for direct consumption; and, in general, it may be said that it brings the highest price in that form. This is especially true if the milk is produced under sanitary conditions and if it can be delivered in high-class condition. Special milks, of course, can be sold at a price that cannot be obtained for any of the other products.

There are various ways of disposing of whole milk. One of the most common is to sell it at a certain price per 100 pounds. For this discussion we shall start with a price of $2 a hundred for 4 per cent milk, and calculate all the other products on the basis of that price. This is not an average price, but will be used simply as an example.

The 4 per cent milk is taken because it is about the test of the average milk.

When milk is sold at a flat price of $2 a hundred for 4 per cent milk, it is, of course, an advantage to the producer to deliver milk that contains no more than 4 per cent of fat. In some states it is not permissible to standardize the milk by separating and adding skimmilk. Where it is not permissible to standardize the dairymen whose cows produce milk richer than 4 per cent are at a disadvantage. It will, therefore, be to their advantage to include the milk of cows that test less than 4 per cent, so that the excess of fat, which is more expensive to produce, is not sold on the basis of 4 per cent milk.

The common practice is to pay a premium for milk that tests over 4 per cent, and deduct a flat rate from milk testing below this amount. To illustrate, one method is to pay 3 cents a hundred more than the regular rate for each tenth that the milk tests above 4 per cent, and 3 cents less a hundred for each tenth that the milk tests below 4 per cent. Let us suppose we have milk testing 4.5 per cent. This milk would contain 0.5 per cent in excess of the standard required, which, at the rate of 3 cents for each tenth, would be 15 cents, so that such milk would sell for $2.15 a hundred. In the same way, milk that only tested 3.5 would sell for only $1.85 a hundred.

Another method is to dispose of whole milk by the quart. Average milk weighs about 2.15 pounds to the quart, so that 100 pounds of milk would be equivalent to approximately 46.5 quarts. If, therefore, we divide $2, the price per hundred, by 46.5, we get an equivalent price in quarts of 4.3 cents. If the milk were sold by the gallon, 17.2 cents a gallon would be equivalent to $2 a hundred.

Still another method of selling milk is at a certain price per pound of butter-fat contained in it. If, therefore, 4 per cent milk were sold at $2 a hundred, it would be necessary to receive 50 cents a pound for the butterfat in order to obtain an equivalent price. A modification of this form is the payment of a definite price for the fat and a definite price for the skimmilk in addition.

In disposing of the milk in bulk, the expense of delivery must be considered when it is necessary to deliver it. The cost of shipping is also a material item, as is the cost of the cans. Many milk com-

panies now, however, collect the milk at the farms, which is sometimes a very material advantage and a considerable saving. This depends upon the market and the city.

The disposition of milk directly to the consumer by the dairyman is a business in itself. Most cities now require that milk be sold in bottles; when the expense of bottling, cost of bottles, cost of cleaning them, and cost of delivery and of collection are considered, the total cost of marketing milk in this form is considerable—often amounting to as much as 4 to 8 cents a quart.

Selling to Creameries, Cheese Factories, and Condenseries.—Various methods of purchasing milk are used by creameries, cheese factories, and condenseries. All the methods described above are used; and, in addition, some cheese factories simply pool the milk, paying a flat price regardless of test; others pay according to test, and still others pay what is known as the "fat plus 2 method." This consists simply of adding 2 to the test, and paying on the basis of this test. This is done for the reason that in cheese-making the casein is as important as the butterfat. The addition of 2 is to bring the relative price a little nearer to what is supposed to be a fair method of paying. For instance, one farmer delivers 3 per cent milk and another 6 per cent milk; if both were paid on the strictly butterfat basis, one would receive twice as much as the other, although the 6 per cent milk might not make twice as much cheese. By adding 2 to each test, the ratio would be 5 to 8, instead of 3 to 6.

Another method is actually to test both the fat and the casein. This, however, is done only to a limited extent. It has been suggested by Van Slyke[1] that the amount of casein be calculated on the basis of the fat content. In either case the actual advantage of disposing of the milk in this way should be calculated.

The condensery usually pays for milk by one or the other of the methods previously suggested. The creamery, on the other hand, usually buys milk on the basis of the fat it contains, and allows the producer the skimmilk, returning, as a rule, about 80 pounds for each 100 pounds of milk delivered. In calculating the price that should be received for a pound of butterfat when milk is disposed of in this way, it is necessary to determine the value of the skim-

[1] Jour. Am. Chem. Soc. 30: 7.

milk. Its value depends largely upon the use to which the producer can apply it. In the feeding of calves it is worth more than can well be estimated, as it is difficult to get a satisfactory substitute for it. When pure-bred animals are being raised and sold, the value of skimmilk is considerable. There is no substitute that will produce the size and keep the thrift in calves that skimmilk will. As calf feed, at the present price of other feeds, it is probably worth at least 40 cents a hundred pounds, although some have shown that it is worth slightly less than this. For the purposes of this lecture, we shall assume that skimmilk is worth 30 cents a hundred. If, therefore, 80 pounds is returned per hundred delivered, the value of the skimmilk returned will be 24 cents. The price that should be received for a pound of fat when the skimmilk is returned is determined by subtracting 24 cents from $2 and dividing the remainder $1.76, by the test given; the result in this case will be 44 cents. On this basis, therefore, 44 cents per pound must be received as an equivalent for whole milk at $2 per hundred.

Selling Cream.—Cream can often be sold for direct consumption at a higher price than that received for the whole milk from which it came. It is also often sold to centralizers for buttermaking, either sour or sweet. Of course a premium is paid for the sweet cream. The following formula may be applied in calculating the pounds of cream that can be produced from a specified quantity of milk of a given test:

Let x = pounds of cream.
a = pounds of milk.
b = test of milk.
c = test of cream.

Then $$x = \frac{a \times b}{c}$$

If we desire to make 18 per cent cream from 100 pounds of 4 per cent milk, by applying the above formula we can find the pounds of cream that would be obtained, thus:

$$x = \frac{100 \times 4}{18}$$

or

$$x = 22.2 \text{ pounds of cream}$$

Therefore, 22.2 pounds of 18 per cent cream can be made from 100 pounds of 4 per cent milk. Table LXXXIX shows that a gallon of 18 per cent cream weighs approximately 8.465 pounds, or a quart 2.116 pounds. By dividing 22.2 by the weight per quart, or 2.116, it is evident that 10.4 quarts of 18 per cent cream can be produced from 100 pounds of 4 per cent milk. If we then divide 200 cents by 10.4 we get 19.2 cents per quart, the price which must be received without including the value of the skimmilk. Table LXXXIX, prepared by Babcock, gives the weight by the gallon of milk and cream.

TABLE LXXXIX

WEIGHT OF CREAM

Per Cent of Fat in Cream	Specific Gravity of Cream	Weight of One Gallon, lb.	Per Cent of Fat in Cream	Specific Gravity of Cream	Weight of One Gallon, lb.
0	1.0360	8.6391	39	0.9919	8.2714
10	1.0243	8.5417	40	0.9908	8.2624
15	1.0186	8.4938	41	0.9897	8.2534
16	1.0174	8.4843	42	0.9886	8.2444
17	1.0163	8.4749	43	0.9875	8.2354
18	1.0152	8.4654	44	0.9864	8.2265
19	1.0140	8.4560	45	0.9854	8.2176
20	1.0129	8.4465	46	0.9843	8.2087
21	1.0118	8.4372	47	0.9832	8.1998
22	1.0107	8.4278	48	0.9821	8.1909
23	1.0096	8.4184	49	0.9811	8.1821
24	1.0085	8.4090	50	0.9801	8.1733
25	1.0073	8.3997	51	0.9790	8.1646
26	1.0062	8.3995	52	0.9780	8.1558
27	1.0051	8.3812	53	0.9770	8.1470
28	1.0040	8.3719	54	0.9760	8.1382
29	1.0029	8.3626	55	0.9749	8.1294
30	1.0017	8.3534	56	0.9738	8.1207
31	1.0006	8.3443	57	0.9728	8.1121
32	0.9995	8.3352	58	0.9718	8.1035
33	0.9984	8.3260	59	0.9707	8.0948
34	0.9973	8.3168	60	0.9697	8.0861
35	0.9963	8.3076	70	0.9595	8.0007
36	0.9952	8.2985	80	0.9494	7.9172
37	0.9941	8.2894	90	0.9396	7.8353
38	0.9930	8.2804	100	0.9300	7.7552

It is essential that cream be carefully standardized so that it will be certain to contain the full amount of fat specified, no more and no less. Even in selling a small quantity, the cream should be tested and standardized daily. Only a short time is required to make the test and to do the standardizing, and even though a very small percentage of excess fat is included, the loss amounts to many dollars a year. In producing cream of a definite standard the best plan is to skim a little heavier cream than the standard sold. By the use of the following formula the amount of skimmilk to be added can be easily determined:

Let x = pounds of skimmilk to be added.
a = pounds of cream produced.
b = test of cream produced.
c = test of cream desired.

Then $$x = \frac{a \times b}{c} - a$$

If it is desired to produce 18 per cent cream and the cream has a test of 22 per cent, and there is 18 pounds of this cream, by substituting in the formula we can obtain the number of pounds of skimmilk which must be added in order to reduce it to 18 per cent.

$$x = \frac{18 \times 22}{18} - 18$$

or

$$x = 4 \text{ pounds of skimmilk}$$

The number of pounds of skimmilk which must be added to produce cream testing 18 per cent in this case is 4.

There are a number of advantages in selling cream. The fresh skimmilk remains for the calves, chickens, or hogs, and there is less product to care for and to deliver to the market than if whole milk were sold. Even though cream is properly taken care of on the farm, daily delivery will be necessary in order to place the best grade on the market.

Making Butter.—The manufacture of butter on the farm adds another enterprise to the dairy industry. The production of milk and the making of butter are two separate enterprises, and the suc-

cess of the second will depend upon the amount of butter made and price that can be secured for it. Milk is sometimes produced in sections so far from the railroads that it is not practical to deliver either milk or cream. In such cases it may be most profitable and convenient to manufacture the milk into butter, which need not be delivered more than once a week. The making of butter requires considerable labor and care in order to make a good, profitable product. Proper care and skill often turn out a product that sells for a price so high as to be the most economical method of disposing of the milk. We shall not discuss here the amount of labor required, nor the equipment, except to say of the latter that it is not very elaborate.

In calculating quantities, the amount of butter that can be made from a given quantity of milk will depend upon the composition of the butter itself. Butter varies in its composition, according to the amount of salt and water incorporated, and to some extent according to the casein content. The law does not allow the manufacture of butter containing more than 16 per cent of water. If we assume 15.9 per cent of moisture with a salt content of 4 per cent, a larger quantity of butter of such composition per 100 pounds of milk will be made than of the grade containing, say, 10 per cent of moisture and 2 per cent of salt. There is some loss of butterfat in the skimmilk and in the buttermilk; but if care is taken in the manufacture of farm butter, to keep the composition under reasonable control, by the addition of such amounts of salt and water as will insure a good product day after day, about one-sixth increase of butter over the amount of butterfat may be secured. From 100 pounds of milk testing 4 per cent, we may expect about 4.66 pounds of butter.

In this case we must make allowance for the skimmilk and the buttermilk. The buttermilk is usually slightly higher in fat than the skimmilk, otherwise their composition is very similar, as will be seen from the analysis in Table LVI. Figuring the value of buttermilk on the same basis as that of skimmilk, and assuming that the two together will be in the proportion of 90 pounds to 100 pounds of whole milk, and that the price will be 30 cents (it may be higher on some farms), 90 pounds would be worth 27 cents. Subtracting 27 cents from $2, we obtain $1.73; this number divided by 4.66

gives us 37 cents, the price that must be obtained for a pound of butter as an equivalent of the price of $2 a hundred for the milk.

This does not take into account the labor required to make the butter, nor the salt and use of equipment. If butter is made it is not necessary to make daily delivery of milk. If the distance is appreciable and the amount of milk small and very little labor and time are required, then it may be profitable to make butter. It may be said, therefore, that if a price of 37 cents or more can be secured for butter, and the skimmilk and buttermilk can be used at a value of 30 cents a hundred, it is as good financially to make butter as to sell milk at $2 a hundred.

The practice of making butter on the farm is fast falling into disuse. Most people are now shipping the cream to centralizers. They need to ship only once or twice a week and so have to go to market their product only about as often as they would if they sold butter. Of course, some butter will always be made on the farm.

Making Cheese.—Cheese is made to a limited extent on farms. The necessary equipment costs about the same as that for making butter, while the labor is relatively more unless the product is made on a larger scale. The actual labor is perhaps not greater, but the time required daily is longer. The entire operation of making American cheese covers a period of about seven hours. On the average, about 10 pounds of cheese can be made from 100 pounds of 4 per cent milk. The whey should be considered a credit item, though it is not worth as much as buttermilk or skimmilk. It has somewhat more fat, but lacks the important constituent casein. Most of the sugar, however, is contained in the whey. It may be fed to fattening animals, but is not good for growing animals unless proper feeds are included with it. Assuming an allowance of 20 cents for the whey in 100 pounds of milk, on the basis of 10 pounds to 100 pounds of milk, it would be necessary to get 18 cents a pound for the cheese in order to obtain the equivalent of the milk at $2 a hundred pounds. This does not include the labor involved. Soft cheese, such as cream cheese and cottage cheese, may also be made. Some of the foreign varieties of cheese may be made, though these form highly specialized industries, require special skill, and also require special prices in order to be profitable unless they are made on a very large scale.

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4. The Market Milk Business of Detroit, Michigan, in 1915, Clement and Waibel, U.S.D.A. Bul. 639.
5. Agricultural Cooperation, Hibbard, Wisc. Exp. Sta. Bul. 238.
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LECTURE XXXIV

MILK PRODUCTION, COST ACCOUNTS, PRINCIPLES, AND METHODS

THE increased knowledge of feeding dairy cattle and of breeding them for higher production, and the growing tendency for farming in general to become more business-like, have been accompanied by a greater attention to the records of the business. The object of better feeding and more intensive breeding is greater efficiency of milk production, and it is becoming more and more apparent that cost determination also is essential to efficiency. It not only furnishes a guide to what should be a profitable selling price, but also enables the producer or manager to direct or control the different factors of cost. A complete and properly arranged cost statement enables the dairyman to study and to compare methods and finally to determine by which method milk can be produced most cheaply.

Importance of a Cost Record.—A cost record is important for more than one reason; it shows the individual producer whether his dairy is profitable and whether some operations cost more one year than another, and it suggests possible means of producing milk more cheaply. A definite and correct system of records, chosen as a standard, should make it possible to compare costs in different sections of the country, and to assist in determining prices that will be fair and reasonable to the producer and at the same time satisfy the consumer that he is paying only what is equitable for the capital, labor, and other expenses necessary to produce milk. Rough estimates may contain errors, and even estimates made with careful attention to details may be far from representing actual conditions.

Although in a great many localities surveys show actual losses in dairying when all costs are included, the fact remains that dairymen are usually successful farmers, and dairy sections and dairy communities are, almost without exception, prosperous. Complete

farm records may show that the dairy farmer may be getting a fair rate of interest on his capital, and a fair wage for his labor, even when cost records show that the profits are not derived from the dairy herd. This is possible when home-grown feeds are charged to the dairy at the prices for which they could be sold, and when the labor in the dairy is actual extra labor that must be paid for. It is evident in such cases that profits are derived from the farm rather than the herd.

These facts should prompt the dairyman to keep cost records, and to endeavor to learn wherein his various cost items are higher than they should be, or higher than formerly. It is to his interest to seek for a remedy. He may discover that a change of rations would reduce expenses, that fewer or more cows should be kept, or that his cows are poor producers. There are chances that the cows are too expensively pastured, or not sufficiently pastured; that he could buy his cows cheaper than he is raising them; that he keeps his calves too long or veals them at a loss. Where the feed prices are figured on a basis of sale or market price, or the price at which they could be purchased in the community, perhaps it would be more profitable to market the crops in the raw state rather than as finished dairy products. In some localities the scarcity and cost of labor also make production of milk unprofitable, and overcapitalization of the dairy may have the same result.

These are only suggestions of some of the factors that may not be known unless accounts are kept. The efficiency of individual cows is of course of great importance. Cows of the same size require about the same amount of feed for maintenance, so that a cow that produces 6000 pounds of milk annually produces it more cheaply per pound than a cow of equal weight that produces 3000 pounds.

Benefits of Cost Records.—A cost record thus possesses not only a direct benefit for the particular dairyman who keeps it, but also an indirect benefit for the public, by helping put the dairy business on a sound basis throughout the country.

The benefits to be obtained by a system of cost accounts for milk production may be summarized as follows:

1. Detection, location, and elimination of waste in material, labor, and other expenses incident to production.

2. Change of operations and determination of actual effect of such on cost.

3. Direction of work by the manager with greater efficiency.

4. Standardization of work.

5. Computation of costs at different times and under different conditions.

6. Provision of reliable statistics for comparisons and studies in different states and localities.

7. Provision of basic data for use in price determination.

Division of Costs of Production.—The costs of production will be discussed under three main divisions: feed expense, labor expense, and indirect expense. "Overhead" or indirect expense will be further subdivided. The following outline indicates the method of treatment:

1. Feed.
2. Labor.
3. Indirect or overhead expense.
   a. Buildings.
   b. Equipment.
   c. Cattle.
   d. Bedding.
   e. Sires.
   f. Miscellaneous.

The credit items which should be deducted as special credits in order to determine the net cost of production are as follows:

1. Calves.
2. Manure.

Relation of Different Cost Items to Net Cost.—Table XC shows the relation of cost items to net cost of production under certain conditions. The feed and labor costs usually constitute 70 to 80 per cent of the total cost of production.

The purpose of Table XC is simply to show the cost factors and their approximate relative proportions to the total cost. Although it may represent actual conditions in some sections at the present time, its purpose is not to show average conditions. Instead of attempting to give any average costs, the authors wish to emphasize the fact that costs vary greatly, and that they are determined by the conditions under which the business must be conducted.

TABLE XC

Relation of Cost Items to Net Cost of Production

		Other Costs (20%)		(10%) Credits
	Labor Costs (25%)		Cost of Production Not Including Distribution Cost or Profit	Net Cost of Production without Profit
Feed Cost (55%)				

Results of several cost studies in different sections of the country are shown in Table XCI. The variation between the results of the different studies is due to differences in the year covered, and the type of dairying, as well as to differences of location.

Reason for Variation in Cost of Producing Milk.—It is no more reasonable to say that it costs 5 cents to produce a quart of milk than to say that it costs 5 cents to make a box. The manufacturer of boxes, before stating a price, asks the size of the box, the kind of material to be used, whether the sides are to be planed, whether the box is to be made and used in the lumber and mill region of Washington State or in New York City, and also whether 10 boxes are to be made in spare time or 10,000 to be made at once.

The milk producer should likewise consider, in quoting or estimating a price, whether it is for 3 or 5 per cent butterfat milk; whether the milk is to be produced from tuberculin-tested cows, and in clean barns by clean labor, or by any cows and without particular care in production; whether it is to be produced where hay is $10 or $20 per ton and grain $25 or $35; whether conditions are such that cows must be kept in the stable all or nearly all the year for

TABLE XCI

COST OF MILK PRODUCTION IN VARIOUS PARTS OF THE UNITED STATES

Items	Study and Year				
	W. Va. Morgantown 1934	Me. 1935	Va. 1932	Ore. 1932	R. I. 1932
Number of records	24	108	107	464	39
Cows per farm	22	19	28	18	20.2
Pounds milk per cow	5,830	6,719*	5,716	6,088	7,566
Per cent butterfat	4.0	4.0	4.0	4.4	
Costs per cwt. milk:					
Feed	$1.29	$1.44	$1.56	$.90	$1.50
Labor	.42	.61	.85	.48	.64
Other	.44	.44	1.19	.40	.86
Total	$2.15	$2.49	$3.60	$1.78	$3.00
Credits	.23	.29	.35	.18	.21
Net	$1.92	$2.20	$3.25	$1.60	$2.79

* Four per cent fat milk equivalent.

lack of pasture, or whether they can feed on grass six or more months of the year, and perhaps on land unfit for other crops. He should also know whether his price is based on a small quantity produced as a side line, or on a large quantity produced as a specialty. It is to obtain an accurate knowledge of these very items of cost, etc., that cost records are needed.

The percentage indicated for feed costs in Table XC may be too low where an intensive feeding system is practiced, that is, where considerable grain is included in the ration. Where summer dairying is the practice, and where roughage forms a large part of the feed, the proportion of labor and indirect cost of production may be greater. Also, in regions where an intensive soiling system is followed, the proportion of labor may be higher. Expensive cattle and buildings increase the proportion of indirect cost. Dairies that are overcapitalized show excessive overhead costs. Some cows are bought at such high prices and housed in such expensive buildings

that no system of feed, no possible production, and no reasonable price for milk could make them profitable.

Necessary Records.—A complete cost of milk production account will be made up of three types of records: inventory, cash or financial records, and supplementary records. These different types are of equal importance, or it may even be said that in dairy management the supplementary records are the most important. Supplementary records that are most needed are records of the milk produced and of the feed fed. Such records are absolutely necessary to intelligent feeding as well as for the cost account. It is necessary for a feeder of milch cows to know just how much each cow consumes, and how much milk she produces. Records of the weight of milk, together with the weight of feeds, make accurate and efficient feeding possible. Methods and forms for keeping milk and feed records that were discussed in a preceding lecture are entirely adequate for this part of the dairy cost account. In addition to milk and feed records, there is needed an occasional weighing of bedding, and simple labor records such as a record of the time spent in doing chores one day each month.

In the order of starting the cost account, however, the inventory comes first. The inventory is a list of the buildings, equipment, and cattle in the dairy herd, along with their values. The list should be detailed enough so that at the closing of the year's account the items may be identified and properly revalued. Problems of valuation and changes in value will be taken up later. The inventory provides data necessary for determining four cost items. They are:

1. Depreciation or cost of cows.
2. Average investment in cows, upon which interest charges are based.
3. Building charges.
4. Equipment charges.

These items make up a large part of the indirect costs, and will be discussed under that heading.

The cash record is the record of the cash expenses incurred in operating the dairy herd, and of the cash receipts from sales of

milk, etc. Nearly every item of cost will be represented by some cash transaction, and so it will be unnecessary to repeat the list here. Each entry made in the cash record should include, besides the amount spent, a statement of the item and quantity purchased. If some thought is given to selection of the record book, or to the forms in which records are to be kept, considerable inconvenience will be avoided both in the keeping of the account, and in the final summarizing and analyzing.

Amount of Time Required to Keep Records.—The amount of time required to keep these records is slight. Milk scales near the milk tank, and a simple chart with the cows' names or numbers and blanks for the different days, are all that is needed for the milk record; and the same scales and a feed chart which can be attached to the feed bin or cart, for keeping a record of the quantity of feed used, as described in a previous lecture, are all that is needed for feed records. For cost account purposes, it may not even be necessary to keep individual feed and production records, since the value of records of the individuals lies mostly in their use for proper feeding and culling. If, in the cash record, an account is kept of the amount of feed purchased for the dairy herd, and of the quantity of home-grown feeds that were used by the dairy, these data will be sufficient. Dairymen who belong to a dairy herd improvement association will find that the feed costs calculated by the tester are all that is needed for this part of the account.

The other items of cost can be kept with even less labor. An occasional weighing of the bedding, simple labor records, and the records of cash expenditures and receipts, that are most quickly entered the same day that purchases or sales are made, complete the data necessary for determining the current expenses of production. The inventory requires from one to several hours of work when it is first set up, but at the end of each year depreciation and the value of repairs and improvements are quickly calculated to complete that portion of the cost account.

Having discussed the necessity for cost of milk production accounts, and the kinds of data that must be kept, we are ready to consider the actual items of cost to be determined from our data.

The Cost of Feed

The largest and most important item of cost is feed. This varies greatly with different cows and with different methods of feeding. The kinds of feeds used, the amounts consumed, and the price have a marked influence on the total cost of producing milk.

Price at which Feed Should Be Charged.—One of the first questions encountered is whether home-grown feed should be charged at cost of production or at market price, the market price, of course, being considered as the price at which it could be sold or purchased. In the earlier days of farm accounting there was considerable difference of opinion as to which cost should be chosen. The cost of production for price may be justified if it is conceded that the feeds produced can be used only by the dairy herd. Then the costs of crop production become costs of milk production. This concept has particular bearing on the evaluation of silage, since silage commonly has no other use than to be fed on the farm where it is grown.

The disadvantage of the use of cost price is that, when it varies greatly from market value, the difference may hide the true efficiency of the dairy herd. When the dairy herd might produce milk at a profit on feed at market price, charging a high cost price for feed cannot justify one in saying that milk production is unprofitable; it is feed production that is unprofitable. Likewise, a cost price of feed that is consistently lower than market price may not justify the production of milk if milk cannot be produced profitably on feed at market prices. In that case, it might be more advisable to sell the feed on the market. With most milk production cost accounts, it is the profit of the dairy that is directly the result and purpose of these accounts; hence market price is most satisfactory. There are also practical reasons for using market price for feeds. One is that additional records must be kept for the satisfactory determination of the costs of producing feeds. Also, in recent years, all dairy cost studies have used market prices for feeds. Since uniformity of cost methods increases the value of the results, this is further reason for using market price. Purchased feeds, of course, are rightfully charged at their cost price plus the cost of hauling them to the farm.

The valuation of silage offers a special problem. Because it has no general market outlet, one common practice has been to charge silage at its cost of production where that cost is known or can be readily estimated. Another way is to evaluate it according to its comparative feeding value. On this basis a ton of silage is usually considered to have a value of one-third that of good legume hay. Still a third way is to evaluate it according to the estimated amount and market value of grain per ton of silage, plus the value of the remaining portion of the corn plant.

The Cost of Roughage.—The cost of roughage varies with the amount eaten and with its price. The amount of roughage that should be fed to a cow under ordinary conditions has been discussed in a previous lecture. It was indicated that there was some range in the amount that could reasonably be fed, and this range is utilized in feeding for the lowest cost of production, or for the most profitable production. When hay is plentiful or low priced in relation to other feeds, the largest possible amount of hay may be fed. With hay scarce or relatively high in price, the amount fed may be limited, and nutrients supplied from other sources. For this reason the amount of roughage costs, and the proportion they bear to the total feed cost, vary from year to year.

The proportion of roughage cost to total feed cost depends also on the production level of the cows. Up to a certain level, milk may be produced from roughage entirely if the roughage is of proper quality. Beyond that point, which varies according to the producing ability of the cows and their ability to consume roughage, increasing amounts of grain must be fed as the production level increases. Consequently, roughage costs may comprise nearly all of the total feed cost where production is low, but where production is high, and especially when grain prices are high also, the cost of roughage may be only one-fourth, or less, of the total feed cost.

Cost of Pasture.—Among all the items of feed cost, pasture cost is as important as any, though it is not so much discussed. In any particular community, the renting of pasture may be so common that a market price for pasturage has been established. It may be justifiable to use this price in such cases. However, in the absence of such a price, or whenever it may be desired to determine the fairness of such a price, the following method of evaluation may be

employed: 1. Determine the number of acres needed to pasture the herd. 2. Estimate the land rental, which should be charged on the basis of a legitimate interest on the value of the land. Five per cent is the basis used throughout this lecture. It is generally conceded that interest should be charged on the value of land that is owned. If interest were not charged on land that is owned, it would be better for the farmer to have his own money invested in good bonds which would return dividends, and to farm on mortgaged land. The interest must be borne by the owner of the land in some way. 3. Estimate the general expense, which includes taxes, making and repairing fences, seeding or reseeding, liming and fertilizing. Pasturage, therefore, would be computed as follows:

1. Value of pasture acreage multiplied by 5 per cent, which may be considered as rent.
2. General expense, which on the average will be about $1.50 per acre.

The calculation of pasture cost for a herd of 20 cows, assuming that 40 acres worth $50 per acre were used, would be as follows:

	For the herd	*Per Acre*
Rent	$100.00	$2.50
General expenses	60.00	1.50
Total cost	$160.00	$4.00
Cost per cow	8.00	8.00

The cost of pasture per cow for the season would be $8.00; or, on a basis of five months, $1.60 per month.

Cost of Grain Ration.—Now that the items of roughage and pasture, which have such an important effect upon the cost of production, have been considered, we shall turn to a consideration of the grain cost.

Variation in costs of grain is the result of many factors. Ordinary feeding practice varies the amount of grain fed according to the amount of milk produced. But the relative price advantage of hay or grain may have an additional effect, as was pointed out in the discussion of roughage costs. With hay low in price, and grain high, it may be more profitable to feed as much hay as possible and to feed less grain. Also with milk selling for a low price, and

feed costs high, less grain will be fed, even if production suffers to some extent. Although in general it is well to have high production to counterbalance the cost of maintenance and the overhead costs of production, the last few pounds of production of many cows cost too much. Often, if one feeds a cow less grain and does not attempt to force her to the very limit, she will produce somewhat less milk, but the total amount of milk secured will be produced at proportionately less cost.

The variations in the amount of grain fed should be the result of careful calculation and the feeder's certain knowledge of the results to be expected, but they may be the result of unreasoned responses to varying conditions of feed supply and feed and milk prices, for little exact information is available as to the most profitable level of feeding for cows of a given producing ability, and for various combinations of feed and milk prices.

In general, however, the amount of grain fed will coincide quite closely with the requirements according to the feeding standards. Because of this, the feed costs obtained from the dairy cost account may be compared with the requirements of the feeding standard to measure the efficiency of the feeding methods. Grain costs, even within the limits of the feeding standards, may range from practically no expense for grain up to one-half or more of the total cost of feed.

Calculation of Feed Costs.—Although it is the intention of this discussion to emphasize the importance of determining costs from records and accounts, it is sometimes desirable to make an estimate of costs. Feed costs especially may be estimated with some degree of accuracy for any assumed conditions of feed price, and weights and producing levels of cows. To illustrate the method, the necessary conditions may be assumed: Suppose that we have a herd of cows which average 1000 pounds in weight; which give an average of 8000 pounds of milk per year; and whose milk contains 4 per cent of butterfat. The first step is to calculate the amount of protein and energy required by the cows. Assume that 20 per cent of the year's feed is secured from pasture. The cows will no doubt be on pasture more than 20 per cent of the days in the year, but they will receive some other feed a part or all of the time they are on pasture. We then have to provide feed for 280 days. By referring

to Table XV and to Table A in the Appendix, we determine the following needs for such cows:

	Digestible Crude Protein, lb.		Total Digestible Nutrients, lb.	
Maintenance	0.70×280	196	7.925×280	2219
8000 lb. of 4% milk	0.60×8000	480	0.328×8000	2624
Total amounts required		676		4843

The cows must be supplied with 676 pounds of digestible protein and 4843 pounds of total digestible nutrients. Now let us assume that we are feeding silage and alfalfa hay for roughage. Referring to Lecture VII we find that a 1000-pound cow can be expected to consume 10 pounds of hay and 25 pounds of silage per day, or 2800 pounds of hay and 7000 pounds of silage for the 280 days. By referring to Table A we find that 2800 pounds of alfalfa hay supply 296 pounds of protein and 1428 pounds of total digestible nutrients. In like manner the protein and energy supplied by silage can be computed:

	Digestible Crude Protein, lb.		Total Digestible Nutrients, lb.	
Amount needed		676		4843
Supplied by hay	296		1428	
Supplied by silage	85		1242	
Total supplied in roughage		381		2670
To be supplied by grain		295		2173

Now by turning to Table A we can select a ration that has a ratio of protein to energy equal to that of the part to be supplied by grain, which is about 1 : 7.4. Such a mixture is supplied by the following ration:

	Digestible Crude Protein, lb.	Total Digestible Nutrients, lb.
300 lb. corn and cob meal	13.28	238.2
200 lb. ground oats	18.50	134.0
100 lb. wheat bran	12.01	59.7
50 lb. cottonseed meal	18.50	40.9
650 lb. mixture	62.29	472.8
Lb. per 100 lb. mixture	9.58	72.74

This ration supplies 9.58 pounds of protein and 72.74 pounds of total digestible nutrients per hundred pounds of mixture. If we divide 295, the amount of protein needed, by 9.58, the result is 30.8, the number of hundredweights of the above mixture needed for the year. Using assumed prices, the cost per hundredweight of the above grain mixture would be calculated as follows:

300 lb. corn and cob meal	@ $1.05 per 100	$3.15
200 lb. ground oats	@ $1.10 per 100	2.20
100 lb. wheat bran	@ $1.05 per 100	1.05
50 lb. cottonseed meal	@ $1.50 per 100	.75
650 lb. of mixture, total cost		$7.15
100 lb. of mixture, cost		$1.10

Summarizing the feed cost, we have the following:

2800 lb. of hay	@ $0.80 per 100	$22.40
7000 lb. of silage	@ $0.25 per 100	17.50
3080 lb. of grain mixture	@ $1.10 per 100	33.88
Pasture for season @ $8.00		8.00
Total cost of feed for year		$81.78

This is higher feed cost than was found in some of the studies reported in Table XCI, and lower than in others. It might be higher if we find that the cows can produce more, if they can get less feed from pasture, if they need less hay and more concentrates, or if the feed prices that we used are too low. The feed cost might be lower if the cows can get more feed from pasture, or if cheaper kinds of feed can be used in the ration. A cost calculation like

this, made with several different combinations of feed, may often show a more economical way of feeding, and this is the most useful purpose of such a calculation.

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LECTURE XXXV

MILK PRODUCTION, COST ACCOUNTS, PRINCIPLES AND METHODS (*Continued*)

THE COST OF LABOR

LABOR, although not the largest item of cost, is of considerable importance in dairy-herd management. It is of peculiar interest because of its various phases and its effects upon the dairy industry. Some dairymen claim to have been driven out of the business because of the difficulty of getting men to work on farms where cows are kept, and others continue in the business because it enables them to keep help the year round, although it may not pay in full for the labor.

On dairy farms where milking is considered merely as a task with which to begin and conclude a day's work in the field, competent steady labor is a problem. Where the milking is considered an essential part of the day's work, there is no more difficulty in keeping good men on a dairy farm than on any other kind of a farm. On large dairy farms, where the hours are definite and the work is regularly performed, labor is not a perplexing question. On small farms the labor is performed at no extra cash outlay and in addition to the field work. When cost records on these farms show that the milk is produced at a loss, it simply means that labor is performed at a lower wage than the figure used in the cost account. Often, however, the farmer is willing to do the work for the increase in income, although it is less than a good wage.

On some farms the women and children do the milking and care for the cows; children that are not at school during the busy season can be helpful in the dairy. Women and children are usually better milkers than men because their hands and muscles are not so hard. The use of child labor on the farm is not to be compared with its use in the factory, since on the farm the children work with their parents and under conditions that are to a certain degree beneficial.

The dairy farm is a good medium for the labor of the farm children. It may not, however, be out of place to say here that the dairy farms, more than any other farms, are driving the boys to the cities. Inferior cows and barns, and milking as extra work, form a depressing environment. In brief, with good cows in convenient, comfortable barns, and their care as a part of the day's work or, better still, assigned as the sole occupation of one or more, as conditions require, dairy work is not objectionable to most boys.

Cause of Variation in Labor Costs.—Labor cost is not so variable on different farms as feed cost—assuming, of course, that milk of equal quality is produced. The system of management and the number of cows kept are important factors. Where labor that could be otherwise employed is used and paid for in caring for cows, labor cost can be reduced by increasing the herd to the number of cows that would make it profitable for one man to devote all his time to the dairy. Less time would be lost, the man would be better satisfied, and the cattle would receive better care.

It often happens that the herd is increased so much in size that there is not enough time for proper attention to feeding and care, or that it is not possible to find competent hired help to do the extra work. If an extra man must be hired, only part of whose time can be profitably spent in the dairy, the rest of his time may be inefficiently used about the farm. These factors decrease the profits of the business and make it difficult for some dairymen, who are producing milk from large herds, to compete with the smaller producer, even with the same grade of milk as a basis. Where the herd cannot, for other reasons, be increased enough to furnish a profitable outlet for extra labor, some dairymen succeed by turning to the production of a higher grade of milk, for which they demand a higher price.

From the standpoint of the actual time required by each cow and the efficiency of labor, the larger dairy is to be preferred. The man who devotes all his time to the cows can give them better care and loses less time. On dairy farms where men are required to combine work in the fields with work in the dairy, much time is lost in changing from one task to another; and a man cannot do as good work in the barn when he also does heavy work in the field.

The number of cows in the herd is a factor to be considered.

Certain operations demand about the same amount of time whether many or few cows are kept. In general, it takes five times as long to milk five cows as to milk one, but twenty cows can be fed or brought from the pasture in about the time required by five. The amount of milk a cow gives is also important; only a little more time is necessary to milk a cow that gives a large quantity of milk than one that produces less.

It is generally possible for one man to do the work of caring for 20 to 25 cows. Where a system of soiling is followed, fewer cows could be attended by one man. Under conditions where 20 or more cows are kept and where pasture is used for several months, a figure of 165 hours for a cow may be required, although with ordinary care this figure can be reduced considerably. This accounts for the full time of a man at 10 hours a day for 20 cows, allowing shorter hours for holidays. If the labor record of the cost account shows a total input of 3300 hours of man labor in caring for 20 cows, this will be about usual efficiency. At a rate of 20 cents per hour, equivalent to $60 per month, the cost of labor will be $660 for the herd, or $33 per cow.

The cost of labor varies widely in different sections and also with the seasons, but the dairy furnishes employment fairly constantly throughout the year. The labor record is desirable to show the returns for labor performed by members of the family who are employed in the dairy.

Does Cost of Manure Offset Labor Costs?—It is the practice of some dairymen, in figuring milk cost, to assume that the manure offsets the cost of labor. This was commonly done by early investigators of dairy costs, but when a record is kept of the amounts of labor used in the dairy, and of the manure produced, it becomes apparent that these two items usually offset each other only at a very low rate for labor, or at an unusually high rate for manure. In any case it is best to keep a record of the labor at least. Then, if it is found that the two values offset each other, there can be no doubt as to the fact. To assume them to be offsetting without the use of records is unbusinesslike, and defeats the purposes of the cost record.

The Milking Machine.—The milking machine is being used to a considerable extent in some sections. Data are available which

indicate that the machine may result in appreciable saving of labor in herds of larger size—at least 15 to 20 cows. The saving in labor is offset to a varying degree by higher equipment charges, so that the economy of a milking machine must be determined on the basis of the value of the time saved. The cost of operating the milker may be calculated separately from other equipment costs by using the inventory and cash records, and this expense can then be compared with the probable value of the time saved. It has been shown in experiments that the machine, in the hands of a careful man, will milk a cow well, and apparently have no injurious effect upon her. It has also been shown that, with especial care, milk with low bacteria content can be produced with the machine.

The Cost of Buildings

So far we have considered feed and labor costs. To be accurate, these will have been calculated from records and accounts. The next item to be considered—the building charge—is usually determined in this same way. However, it is largely dependent on the value of the buildings; hence, the probable building charge can be quite accurately estimated as soon as inventory has been taken. Moreover, once the buildings have been provided for the herd, the building charges continue at about the same level regardless of booms or depressions in feed, labor, and other items of cost. The building charge is the largest item of all the indirect costs, and is made up of the following items:

1. Interest on investment.
2. Depreciation.
3. Repairs.
4. Insurance.
5. Taxes.

All these items, except repairs, are calculated from the inventory valuation at fairly uniform rates from year to year. They are a total charge against the herd, regardless of whether or not the buildings are used to capacity. Consequently, a program of building should be very closely fitted to the size of herd that will be kept. Overinvestment in buildings results in unavoidably high cost.

The amount of the building charge may vary from 1 per cent to 15 per cent of the total cost of milk production under ordinary conditions, with the average around 5 per cent.

Buildings to Be Charged to Cows.—It has been the practice in some cases to include the stables for cows and storage barns for hay as the buildings to be charged to the cows. When hay is charged to the cows at market price, varying throughout the year, it is not just to charge them with the storage barns also. The hay barn is necessary, even if cows are not kept. If the price of hay charged to the cows, however, is based on the price of purchase of the year's supply in hay-making season, the storage will of necessity be included in the cost of milk production.

The milk house is becoming a necessary building, and is properly included in the building charge on farms selling cream or whole milk at wholesale. Retail dairies, and farms making butter or cheese, may more properly include the milk house as a cost of distributing or processing, rather than as a cost of milk production.

Causes of Variations in Cost of Barns.—The cost of a barn for dairy cows varies widely, according to its durability, type of construction, convenience, and sanitary condition. Whether it pays to build at present more substantial barns, barns that will depreciate less and be less subject to destruction by fire, is a question. Methods of housing have changed frequently. The best shape or size of barn has not yet been definitely determined. There has been a tendency to construct, for the housing of dairy cattle, expensive barns to insure the production of especially clean milk. In some cases cows are kept in barns so expensive that the overhead charges of interest, taxes, and insurance have made profitable milk production an impossibility.

The comfort and health of the animals, however, must be maintained. The present tendency is to build less expensive barns, or to provide only open sheds for dairy cows. In many sections this will greatly decrease the overhead expense, keep the cows in a healthier condition, and decrease the cost of labor. The milking parlor or open-pen type of barn has been growing in favor. This arrangement does away with expensive milking barns and greatly reduces the amount of labor, since it reduces the amount of space to be kept clean for milking. A certain amount of expenditure for the

sake of convenience in barns, however, often lowers the cost of production by greatly decreasing the cost of labor.

Since the open shed and milking parlor types of housing have not come into general use, the examples of building costs that will be given here will be for permanent closed buildings housing the cows in individual stalls.

The materials used in building barns have been discussed in a previous section. The more durable materials—concrete or tile—have higher original costs, and hence higher interest charges; but because of longer life the rate of depreciation is lower. Fireproof construction entails higher first costs, which must be compared with the lessened risk of loss. An important consideration affecting both the choice of barn design and barn materials is the present or probable future existence of legal requirements for the production of milk for fluid consumption. Practically all large cities and most small ones have milk ordinances which fix standards for the health, housing, and handling of dairy cows. These standards are not uniform in their requirements, but there is a tendency toward uniformity, the Standard Milk Ordinance of the United States Public Health Service usually serving as a guide. Because of these changes, buildings which will meet present requirements, if not in conformity with the Standard Milk Ordinance, may be inadequate with future changes in the local requirements.

Number of Cows a Factor in Cost of Buildings.—The number of cows to be kept in a herd is a factor in the unit cost of buildings. The cost for a cow is less in a 50-cow barn than in a 20-cow barn of the same construction. The cost by the cow for the barn varies in good dairies from $50 to $100 or more per head. A 50-cow barn of modern construction, such as hollow tile or a concrete barn with concrete floors, walls and ceiling, can be built for about $80 per head. This is for a good barn with a proper ventilating system and modern sanitary arrangements, for a specialized dairy capable of meeting all requirements for the production of a high grade of milk.

Interest, Insurance, Depreciation, and Taxes.—Interest on the investment may be figured at 5 per cent. The insurance will be from 0.2 to 0.4 per cent, according to the relation of the barn to other buildings, etc. The taxes will vary considerably according

to the locality and method of assessment. If assessed at one-half value at a rate of 2 per cent, the item of taxes would be 80 cents per cow per year. Depreciation is normally calculated on the original value of the building according to its expected life. The usual life of farm buildings is considered to be 50 years, which gives a rate of depreciation of 2 per cent per year. It is common practice to calculate depreciation on the basis of the beginning inventory value of the buildings regardless of their age. Then it is necessary to use a higher rate of depreciation for old buildings in order that their original value will have been written off within the expected life of the buildings. The cost of improvements, such as a new roof or remodeling, is added to the value of the barn. Smaller repair items are counted as a current expense. Usually the charge for repairs is determined from the cash record of the cost account. For purposes of estimation, however, it is acceptable to calculate repair costs at 2 per cent of the original value of the buildings. Thus the combined depreciation and repair charge will amount to 4 per cent of the value of new buildings.

A summary of the cost of a building under the above conditions would be as follows:

Interest	\$80 @ 5%	\$4.00
Insurance	\$80 @ 0.3%	0.24
Taxes	\$40 @ 2%	0.80
Depreciation and repairs	\$80 @ 4%	3.20
Total building charge per cow		\$8.24

Cost of Equipment

Considerable equipment is used in the dairy, with a consequent cost for this item. Milk cans, pails, milking machines, stanchions or tie chains, watering equipment, coolers, separator, hot-water equipment, veterinary equipment, forks, shovels, feed carts and litter carriers are only a part of the list. Yearly depreciation of the different articles varies from 2 to 50 per cent of their value, so that it is more difficult to make an estimate of the average rate than it is for buildings. Items of interest and repairs are combined with equipment depreciation to make up the total equipment cost. Equipment cost is greatly affected by the type of dairying being done. A small herd kept as a side line, and producing cream

for butter, may have the very lowest equipment cost. A large dairy producing milk of high quality for fluid consumption, using milking machines and a mechanical cooler, for example, will have a high equipment cost. Many times, when considering whether or not to install a new article of equipment, the farm operator fails to consider the effect on his costs of production. Often only the cost of operating or maintaining the equipment is figured on when probably interest and depreciation charges are much larger items, even if they are unseen. A wise selection of equipment, however, may pay for itself many times over by saving labor or by making it possible to put out milk of a higher grade.

A summary of equipment costs per cow for farms in one fluid milk market was found to be as follows:

Depreciation	$1.50
Interest	1.00
Repairs	0.25
Total per cow	$2.75

The Cost of Cows

Assigning Inventory Values.—One of the principal problems in making up an inventory for a dairy herd is the valuation of cows in the herd. Cows that have been recently purchased, of course, will be inventoried at their purchase price. The remainder of the herd may be thought of as consisting of three classes. A definite procedure may be followed in valuing the animals in each class. These classes will consist of: (1) two-year-olds not yet having production records; (2) three-, four-, and five-year-olds; and (3) older cows.

The valuation of two-year-olds is essentially the problem of setting a value on heifers that come fresh. Authorities differ as to which of two prices should be used—market price or cost of production. Cost price is advocated by those who hold that the raising of heifers is an inseparable part of the dairy business. That is not strictly true. It may be especially desirable that dairymen should choose to raise their own replacements, but the important point is that the choice is theirs to make. There are successful dairymen who purchase all their replacements. It would seem then that

market price might determine the proper value for heifers. For home-grown feeds, we did decide to use market price. However, heifers purchased on the open market are at a disadvantage with home-grown heifers in certain respects. It is difficult to evaluate this difference in terms of price; hence there is this weakness in the use of market price. Sometimes it is attempted to justify one of these prices by determining which one results in the fairest replacement charge on the herd. In this respect either price may be the better, depending upon conditions on the particular farm, in the particular part of the country, or in different years. Cost of production may be excessive or market prices may be inflated, and then either price taken as a standard is unfair to the dairy herd. If conditions on a particular farm make the cost price low, or if in a particular year the market price is low, the dairy herd will have an apparent profit that is not due to the management of the herd itself.

The above statements are not a comprehensive list of the difficulties arising from the use of either market price or cost price alone. They serve to indicate that the most reasonable procedure is to evaluate heifers by taking into account: (1) the quality of the heifers; (2) the normal market price of heifers of similar quality; and (3) the cost of raising heifers. In this way special stress may be placed on normal market value. The allowance for a higher cost of raising them will be made if it is thought that the difference represents an additional guarantee that they will be satisfactory replacements.

After a value has been set upon the two-year-old heifers, there is next to be valued the group containing the cows up to about five years of age. These cows will have completed one or more lactations. They may be given values according to the producing ability they have shown; and because the value of two-year-olds will have been discounted to some extent, as an allowance for the risk of poor production, the value of a three- or four-year-old may be increased if her performance permits it. It is only in this range of ages that a cow may be given a higher value at the end than at the beginning of the year. As she approaches five years of age her life expectancy decreases, and this acts to offset any increase in her value due to a more certain knowledge of her producing ability.

For cows over five years of age, it must be determined how long they will probably be in the herd as profitable producers of milk, and how much they will be worth at the end of their period of profitableness. The amount of yearly depreciation will depend upon the number of years the cow is profitable, and it is represented by the difference between her original value and her sale price as beef. A cow that remains healthy, and is a good producer, may be expected to remain in the herd until twelve or thirteen years of age. If we assume twelve years to be her age at leaving the herd, then she will have seven years in which to depreciate from her maximum value to her beef value. One-seventh of this total then will be her yearly depreciation. To make this clear we may use a numerical example in which the cow is worth $110 at five years of age, and for beef only $40 at twelve years of age. Expressing depreciation as a formula we have:

$$\frac{\text{Highest value} - \text{Final value}}{\text{Interval between ages of highest and final value}} = \text{Depreciation}$$

or

$$\frac{\$110 - \$40}{7} = \$10$$

Thus, this cow that was worth $110 at five years of age in the beginning inventory would be worth $100 at six years of age in the ending inventory of our cost account.

In case of injuries or the effects of disease that are not serious enough to cause the cow to be sold for her salvage value, her inventory value should be decreased according to the extent of the injury. Loss of one quarter of the udder, for example, will decrease her value about one-third; loss of two quarters will decrease her value about one-half.

Length of Time a Cow Remains in the Herd.—In the preceding paragraph we have stated that a cow may be expected to be profitable up to twelve or thirteen years of age or more. This gives a length of life in the herd of ten or more years, and may be safely followed in valuing individual members of a herd. As an average, however, such a figure is almost never attained in practice, and cannot be used in estimating the costs of milk production. If we

examine the hazards facing a two-year-old heifer as she freshens for the first time, we can see why the average is nearer five years than ten. Briefly, these hazards may be classified as:

1. Failure to develop into a good producer.
2. Loss of profitability because of disease.
3. Raising of the standard of profitability during her lifetime.

The amount of loss from each of these factors may be very slight. In well-managed herds, with a relatively low level of production required, the losses may be so slight that the average length of productive life may approach ten years. Where rigid culling must be followed to keep a high production level; where diseases, particularly breeding troubles and mastitis, are prevalent; or in herds where new and higher standards of profitability are established from year to year; the length of life may be even less than five years. Death losses are a factor of varying importance. Various studies of dairy costs have shown death rates ranging from 1.31 to 5.5 per cent.

Taking the above factors into account, various studies have shown the average length of productive life to be from four to seven years, five years being the most generally agreed upon. This is the figure that may be taken as an average for estimating cow depreciation. That is, if we want to estimate the average depreciation per cow for the herd, we will use five years as the average length of life, and calculate the average depreciation by the following formula:

$$\text{Average depreciation per cow} = \frac{\text{Average value when entering herd} - \text{Final value}}{\text{Average length of time in herd}}$$

Herd Depreciation from Cost Records.—The determination of the average depreciation per cow in the herd from a cost record is by a somewhat different method than that followed in estimating depreciation. The total value of all cows in the beginning inventory is added to the cost of all cows purchased and the value of all heifers that freshened during the year. From this sum is subtracted the total value of all cows in the ending inventory plus the price received for all cows sold. The difference is the total depreciation for the herd, and when divided by the average number of cows in the herd gives the average depreciation per cow. Under certain

circumstances, when a large part of the herd consists of two- and three-year-old cows, or when a number of cows have been sold at prices higher than their inventory value, the total of ending inventory values plus sales is greater than the total value of the beginning inventory plus cost of purchases and heifers freshening. The difference is known as appreciation, and appears in the cost summary as a credit to the herd. The following is an example of this method of calculation:

	Number	*Total Value*	
Beginning inventory	20	$1700	
Purchases	2	235	
Heifers that freshened	4	320	
Total	26		$2255
Ending inventory	22	$1870	
Sales	3	133	
Died	1	...	
Total	26		$2003
Total herd depreciation			$252
Depreciation per cow			$12

$$\text{Average number of cows} = \frac{\text{number at beginning} + \text{number at end}}{2} = 21$$

The cost of cows in the above herd may be summarized as follows:

Depreciation		$12.00
Insurance	$85.00 @ 0.3 per cent	0.26
Taxes	$42.50 @ 2 per cent	0.85
Interest	$85.00 @ 5 per cent	4.25
Total cost per cow per year		$17.36

The Cost of Raising Heifers.—In a preceding lecture the reasons for and against raising one's own heifers were given. When these reasons have been considered, a record of the costs of raising one's heifers may be of some help in deciding whether to raise or buy. A number of studies made of the costs of raising heifers show that feed and labor constitute from 80 to 94 per cent of the total cost. A study of the amounts of feed and labor used in raising heifers in West Virginia is shown in Table XCII.

TABLE XCII

AMOUNT OF FEED CONSUMED BY HEIFERS UNTIL THEY WERE TWO YEARS OF AGE

Whole milk (lb.)	826
Skimmilk (lb.)	1323
Grain (tons)	0.32
Hay (tons)	1.4
Pasture (months)	11.0
Labor (hours)	65.

These heifers were mostly of Jersey breeding. Heifers of the larger breeds would require more feed than this. However, with these data one can calculate the costs. If we assume the same prices for feeds as we used in figuring the cost of feeds for cows, with skimmilk at 25 cents a hundred, whole milk at $2 a hundred, grain at $22 a ton, hay at $16 a ton, and pasture cost at 80 cents a month, then the total cost of feed will be $58.07. Labor at 20 cents an hour would cost $13, bringing the combined feed and labor cost to $71.07.

The other expenses, including interest, buildings, equipment, bedding, loss by death, and miscellaneous expenses, are variable; but a reasonable estimate is $15. This makes the total cost of raising the heifers, including feed, labor, and overhead charges, $86.07. A credit of $12 for manure may be allowed, which makes the net cost of a two-year-old heifer $74.07.

An initial charge for the calf may or may not be included. If there is a market available for three- or four-day-old calves, then it is proper and necessary to charge the heifer account with the value of the calf at that age. (Later it will be seen that the cow is credited with this value.) If calves not kept to be raised are slaughtered at once, then there should be no initial charge for calves raised.

THE COST OF BEDDING

Bedding is a small item on a farm with a small dairy, especially if the location is at some distance from the city or from markets. In localities where straw can be sold at a good price and where a large number of cows are kept, bedding is a material item of cost. A great many substitutes have been found for bedding for dairy

cows, sawdust and shavings being the most common. These are quite general on farms where high-quality milk is produced, because of the difficulty of getting straw that is free from dust. It is thought by some that sawdust and shavings are injurious to the soil, though this has not been demonstrated. It is certain, however, that the manure is not so valuable as when straw is used. Waste hay and stover are also used for bedding, but these materials ordinarily contain too much dust.

When the cows are kept tied in rows and on a platform, the shavings and sawdust do not involve so much work, and they keep the cows cleaner. Baled shavings are preferred to all other kinds of bedding for they can be handled with less labor, will absorb the liquid manure well, will stay where placed, making it possible to keep the cows cleaner, and are relatively freer of dust than straw or stover. Where the floor is light and smooth, both sawdust and shavings can easily be removed.

The amounts of the various beddings needed will depend upon the management, the length of time the cows are kept in the stable, and the nature and condition of the floor (see Lecture XVIII).

The Cost of the Sire

Two factors determine the cost of the sire for a cow, namely, the expense of keeping the sire, and the number of cows served. The first cost of bulls varies greatly, ranging from the cost of raising to hundreds and even thousands of dollars. It requires, for a particular herd, no more expenditure to raise a good bull than a poor one, but the initial cost is more; and if the bull gives especial promise, or has been tried and has produced especially good animals, his sale price and also his intrinsic value may be very high. The influence of a sire that will get daughters with greater productive ability than their dams is worth much to the herd that is being developed.

From the standpoint of the cost of producing milk, we do not need to consider the costs of keeping the very expensive bulls. Wherever such bulls are found, the dairy business will be most concerned with the production of pedigreed breeding stock, and not with

the production of milk. A bull that will be likely to give calves equal to or better than the 8000-pound producers taken as a basis of calculation in a preceding chapter would cost perhaps $50 when a few days old. It would cost somewhat more to raise a bull to two years of age than to raise a heifer to that age, but the bull could be used moderately during its second year. It is reasonable, therefore, to assume a cost of $100 for the bull at one year to one and a half years of age.

The expense of keeping a bull is somewhat different from that of keeping a cow. More room and more bedding are required, but the feed is somewhat less than that required by a high-producing cow. The taxes, interest, and insurance should be considered on the same basis as for the cow. The depreciation is greater because the initial cost is higher; and the period of usefulness in a herd is no longer, on the average, though the bull may sometimes be sold for use in another herd at a price greater than he would bring as beef. A bull is usually heavier and, unless old, will sell for more as beef than a cow. On the average, four years is as long as a bull can be used to advantage in one herd, unless a large herd and several bulls are kept. In this case the bull can be used with cows descended from other bulls.

The amount of labor spent in care of the bull is more variable than that spent on cows. It depends on whether the bull is pastured part of the year or dry fed the year round; whether he is kept in a stall all the time or has an exercise yard into which he may go at will. The bull may require as much labor as an average cow, but on most farms the time spent on the bull will not exceed 65 hours per year.

If the bull is stabled in the dairy barn, part of the building charge should be allotted to bull costs. If a separate bull shed, exercise yard, and breeding chute are kept for him, the cost of these will be added. Likewise the equipment specially used in his care—staves, rings, ropes, watering equipment, etc.—will be represented by depreciation, interest, and repair items, combined as equipment cost.

There may be other items of costs also, and these may be grouped as miscellaneous expenses.* On the basis of $100 for the

sire, the following costs may serve as a guide for estimating the cost of a bull for a year:

Feed	$50.00
Labor, 65 hours @ 20c	13.00
Depreciation, $100 to $60 in 4 years	10.00
Interest on $100 @ 5%	5.00
Taxes and insurance	1.30
Buildings	8.00
Equipment	2.00
Miscellaneous	1.00
Total cost per year	$90.30
Credit for manure	12.00
Net cost per year	$78.30

The number of cows served by the bull is the greatest factor in the cost per cow. A bull will serve as many as 100 cows during the year, or even more; but in practice the service is not regular, although an attempt is commonly made to have fresh cows at different seasons. It should also be remembered that there are seldom as many as 100 cows in the herd. The greater part of the milk of this country, as already suggested, is produced by small herds; and it is in these that the cost of bull service is so high, especially where expense bulls are kept. Bull associations, wherein bulls are rotated from farm to farm as their period of usefulness in each herd is over, provide a means of decreasing the cost of service.

Following the foregoing table, with a herd of ten cows the service for each cow would be $7.83 a year, whereas in a herd of twenty cows this cost would be only one-half as much.

Miscellaneous Expenses

In a well-equipped dairy the miscellaneous expenses are considerable. Some of the items which are common will be discussed here, but one or more of them may not be necessary as costs for a particular dairy. For example, some dairies are located near good springs or are supplied with an abundance of cold water, so that ice is not needed. The expense of cooling milk, however, will usually be an item, whether it is present as a charge for ice, water, or electricity and equipment expense for a mechanical refrigerator. If ice is used, about one ton yearly per cow will be required.

Whether this is the most economical method of cooling depends on the individual farm, but it will do as an example of what must be considered. Wood and coal for heating water, and for steam where sterilizers are used, add another annual expense item.

Electricity is an item of expense found on an increasing number of farms. The number of jobs that may be done by electricity is very large, consequently the amount of expense for electricity will vary greatly. A dairy using electricity for lights and the milking machine may have a charge of 75 cents per cow per year for this item.

Supplies, such as medicine, salt, soap, disinfectant, and fly exterminator, cost from a few cents to a dollar or more per cow.

Another incidental expense is that for the services of the veterinarian and of the supervisor of the dairy herd improvement association. In the average dairy the dairyman should be able to treat ordinary diseases and should seldom be obliged to call a veterinarian. An occasional visit from the veterinarian, however, is necessary, particularly in connection with the testing for tuberculosis and Bang's disease. The supervisor of a testing association does a necessary work in herd management, and he can usually do it cheaper and better than the dairyman. The cost of this service depends upon the size of the herd. An average charge of $2.50 per cow annually will cover it in most localities, and the veterinary fees ought not to exceed 50 cents to $1 per cow yearly.

Most dairymen in the larger milk markets now belong to some organization of producers which handles the marketing of their milk. Such organizations bargain with milk dealers, check the accuracy of tests, weights, and payments, and carry on educational campaigns to promote the sale of milk. To support these services the members contribute a fee ranging from 2 to 4 cents per hundred pounds of milk sold through the organization. This also is an expense to be charged to the herd. For the 8000-pound cow, 90 per cent of whose milk is sold, at a check-off of 2 cents per 100 pounds this will amount to $1.44 per cow per year.

Usually the milk must be hauled some distance to a country or city milk plant. The expense of hauling becomes a large item if the distance is great or if only a small amount of milk is hauled. In well-developed dairy sections the hauling is done by a contractor

who, by hauling several patrons' milk, can do the work more cheaply. The rates charged may vary from 15 to 30 cents or more per hundredweight of milk. Assuming a rate of 20 cents, the cost of hauling per cow, when 90 per cent of her 8000-pound production is sold, will be $14.40.

All these miscellaneous costs may be brought together as follows:

Ice, one ton at $3.00	$3.00
Wood and coal	0.50
Electricity	0.75
Supplies	1.00
Veterinary services and tester	3.50
Organization fees	1.44
Hauling milk	14.40
Total miscellaneous expenses	$24.59

These items cover conditions that are above the average, but no better than are necessary for the production of high-grade milk, such as is required if the wider use of milk is to be encouraged. Most farms use no ice, no coal or wood for steam, and no sterilizers. The item of supplies may sometimes be reduced. The cow tester is not employed on most farms; but this is not a real saving for generally the cost of his services is returned many times by the increased efficiency of the herd. Not only do the records of the supervisor of the dairy herd improvement association show the profitable and unprofitable cows, but the tester is a great help in the selection of calves to be used in future herds, and in finding sires with ability to transmit high production to their offspring. The result is to make intelligent breeding and herd improvement possible.

Credits

The cost of keeping a cow is not alone the cost of producing milk since calves and manure are also a result. It would be proper, if it were possible, to determine just what the cost of each of these by-products is. Subtracting this from the total cost of keeping the cow would give us the cost of producing milk. Such a method is not practical, but it has become customary to figure that the cost of producing calves and manure is just equal to the value of the product. Hence, by subtracting the value of calves and manure from the total cost, the net cost of milk production is determined.

Calves.—A calf sold at the age of three or four days may be credited to the herd at the price received for it. This is the general practice. With calves that are kept to be raised, however, evaluation is another problem. The best solution seems to depend on the local market for calves. If it is generally possible to sell calves at three or four days of age, there is good reason to credit the herd with the market price at that age of calves that are raised. On the other hand, if the only alternative to raising the calf is killing and burying it, then no value should be credited to the herd. In any event, when calves are raised, the value credited to the herd will be the same as that charged to the heifer account.

When calves are vealed, being nursed by cows in the milking herd, it is apparent that all the costs of producing that veal will have been included in the cost of maintaining the herd. Consequently, it will be proper to credit the herd with the value of the veal produced. If, however, a separate account is kept of the amount of labor, milk, and feed that is given to the calf, the herd should be credited on the same basis as if the calf were to be raised. In this latter case, however, it may be possible to credit the herd with some value for the calf, even if no local market value is established for three- or four-day-old calves. Under ordinary conditions the value of calves as given above will not exceed three or four dollars. Because of deaths and breeding irregularity, the number of calves disposed of will be only about three-fourths of the number of cows in the herd, so that, when estimating costs of production, the credit per cow will be three-fourths of the value of a calf. When calculating average calf credit per cow, the cost account, the total value of calves credited, divided by the average number of cows in the herd, will give the desired figure.

Manure.—The actual value of manure produced by dairy cows depends upon the kind of concentrates and roughage fed, the nature and condition of the soil, the productive value of the land, and the value of the crops grown. In making cost estimates, various methods have been followed to calculate the credit to be allowed each cow for manure, and values of $5 to $36 have been given. For the dairy cost account it is most practical to keep some record of the amount of manure hauled onto the fields, and to multiply this by some given value per ton. On this basis, one can expect to get 6 to 8 tons per cow, with a value of about $2 per ton.

Whether this is an accurate value or not may be questioned, but although there are methods that theoretically should give an accurate value, practically they also are approximations. The first of these methods bases the value of the manure upon the cost of mineral fertilizers required to supply the fertilizing elements in similar amounts. If the soil of a particular dairy farm needs these elements, and if they must otherwise be obtained in mineral fertilizers, this method appears to be sound. In addition to the mineral elements, the humus furnished by manure is of considerable value on some fields, though others seem to respond as well to commercial fertilizers when a proper rotation is followed and green crops are turned under. However, the value of manure is thought by some to be overestimated when based on the fertilizing elements it contains. Where the full amount is credited at the cost price of the elements, and where the cows are fed a heavy grain ration, a large figure for manure is obtained. In an experiment by Roberts in which eighteen cows were kept in the stable and given a fairly liberal ration, the results indicated in Table XCIII were obtained.

TABLE XCIII

AMOUNT AND VALUE OF MANURE OF A DAIRY HERD

	18 Cows for One Day	Average for One Cow per Day
Weight of cows, pounds	20,380	1132
Food consumed, pounds	1,347	75
Water drunk, pounds	876	49
Total excretions, pounds	1,452.5	81
Nitrogen, pounds	7.35	0.41
Phosphoric acid, pounds	5.01	0.28
Potash, pounds	7.40	0.41
Value of nitrogen	$1.10	$0.06
Value of phosphoric acid	0.35	0.02
Value of potash	0.33	0.02
Total value	$1.78	$0.10
Value per ton	2.27	
Value per animal per day	0.093	
Value per 1000 pounds live weight per day	0.082	
Value per 1000 pounds live weight per year	29.82	

The liquid manure is included. The value is based on a price of 7 cents a pound for phosphoric acid, 15 cents for nitrogen, and 4.5 cents for potash.

From this must be subtracted the cost of hauling the manure to the field. At 50 cents a ton, and on a basis of 12 tons, the deduction is $6, leaving the value for manure at about $23. With the best of care, fermentation and leaching will result in the loss of part of each of the elements. Where the manure is allowed to stand in open piles exposed to the weather, one-half or more of its value may be lost. While the cows should not be charged with the results of careless handling, it is possible to make only an approximation as to what might reasonably be saved. Some authorities have calculated the value of manure on the basis of 80 per cent of fertilizing elements contained in the feed. This may be too liberal a figure, but it serves the principal purpose of this method, which is to emphasize that the value of the manure is dependent to a considerable degree on the kind and amount of feed fed. Feeds high in protein make much the most valuable manure.

Another method is to compute the value of manure on a basis of increase in the value of crops. Such a plan was followed in farm management studies by the United States Department of Agriculture. The average value of crops—corn, potatoes, wheat, oats, and hay—on well-stocked farms in Pennsylvania was given as $15.80 for each animal unit more than on similar farms with few animals. In similar studies in Michigan the corresponding figure was estimated at $8.22. The difference was accounted for by a supposedly greater need for mineral matter in the Pennsylvania soil, and by better care given manure in Pennsylvania. This difference shows that the value depends upon the conditions and needs of the soil of the dairy farm and must, to a large extent, be calculated with respect to each particular case.

The practice in England, which is covered by a law affecting landlord and tenant, gives a tenant credit for all manure resulting from purchased feeds given to stock, on a basis of three-quarters of the total value of the phosphoric acid and potash in the feed, allowed for all unused manure. A credit of 70 per cent of the total value of nitrogen is allowed when the stock is fed on pasture, and of only 50 per cent when it is fed in the barnyard. When one crop

has been grown after application of manure, a credit of one-half the above amount is allowed.

Skimmilk.—On farms where only butterfat is sold, the skimmilk being fed at home, the value of the skimmilk is considered a credit, and the object of the cost account is usually to find the cost of producing the butterfat. The amount of skimmilk produced is usually estimated at 80 per cent of the total milk production. The value of skimmilk is variable, depending to some extent upon the use made of it. Feeding experiments show that when fed to hogs in a reasonably well-balanced ration it is worth one-fourth to one-fifth as much as 100 pounds of grain. For calves and chickens it may be worth more than this. On this basis, with grain at $1.10 per hundredweight, it would be fair to value skimmilk at 30 cents per hundredweight. At this rate, an 8000-pound producer would have 6400 pounds of skimmilk worth $19.20 as a credit.

Summarizing the Cost Account

An attempt has been made in the preceding discussion to show how each of the items of cost may be calculated from the cost account. These items may now be brought together in the form of a summary. The summary enables one to compare one year's work with another in the most convenient manner, and to see most easily the items of cost that are most in need of attention.

Under the conditions assumed for each item, which include a particular size and kind of cow producing 8000 pounds of 4 per cent milk, with feeds at stated prices, with the system of management given, and with a good barn well equipped for the production of high-grade milk, our summary takes the following form:

Costs:		
1. Feed	$81.78	
2. Labor	33.00	
3. Buildings	8.24	
4. Equipment	2.75	
5. Cattle	17.36	
6. Bedding	3.25	
7. Sire	4.02	
8. Miscellaneous	24.59	
Total		$174.99

Credits:		
1. Calves	$3.00	
2. Manure	16.00	
Total		19.00
Net cost per cow per year		$155.99
Net cost per 100 pounds of milk sold and used on the farm		2.05

For purposes of estimating returns, the amount of milk sold and used on the farm may be taken to be 95 per cent of the amount produced. The average of records on a large number of farms has shown that there is a loss of about 5 per cent through spilling and wasting. An 8000-pound producer therefore will have 7600 pounds for sale and home use. On that basis the net cost of producing milk under the conditions given above will be $2.05.

Returns

In the cost account, record will have been kept of the amount and value of milk sold, and of that used on the farm. The profit will, of course, be the difference between the net cost and the total value of milk sold and used on the farm. Estimating the value of milk sold and used to be $2.25 per 100 pounds, the returns for milk per cow in the preceding problem will have been $171, leaving a profit of $15.01. Often the returns are expressed as a return per hour of labor. By this method the cost of labor is added to the profit and the sum divided by the number of hours of labor. Under the above conditions, the return per hour of labor would be:

$$\frac{33.00 + 15.01}{165} = 29 \text{ cents}$$

Since it is difficult to distinguish between what is payment for the manager's ability and what is really profit, the return per hour of labor is less misleading than charging an arbitrary cost of labor and calling the rest profit.

Cost of Milk Production with Low Producers

So far, the costs have been figured for cows producing 8000 pounds annually. If the average production considered were only 3000 pounds, then there would be a very difficult outlook for the

business. The principal difference in costs would result from the smaller amount of feed needed. The cost of labor, buildings, equipment, and bedding would be the same. Sires suitable for herds with this level of production would be slightly less expensive, and the cows would have a lower value, resulting in lower cow costs. We may assume that the value of the bull and of the cows would be about $60. Assuming that other rates would remain the same, the costs for 3000-pound cows would be:

Costs:		
1. Feed	$55.80	
2. Labor	33.00	
3. Buildings	8.24	
4. Equipment	2.75	
5. Cattle	7.78	
6. Bedding	3.25	
7. Sire	3.39	
8. Miscellaneous	14.69	
Total		$128.90
Credits:		
1. Calves	$3.00	
2. Manure	16.00	
Total		19.00
Net cost per cow per year		$109.90
Net cost per 100 pounds of milk sold and used on the farm		$3.86

The net annual cost of the milk produced by cows of this kind would be $109.90. The milk, at the same price, $2.25 per 100 pounds, would bring $61.88, which would result in a loss of $48.02 for each cow each year. This is what may be expected at the above prices of feed and labor from cows that produce no more than 3000 pounds, when a dairyman attempts to produce milk of good grade, in good barns, using full grain rations, and practicing year-round feeding.

The conditions that exist where 3000 pounds would be normal production would probably be somewhat different from those given above. Less expensive buildings would be used; the cattle would be kept on pasture and fed chiefly straw and stover during the winter; the bedding would consist of refused roughage; the equip-

ment would be relatively incomplete and inexpensive; and less grain would be fed, the cows producing most of the 3000 pounds while on pasture. The item of labor under this system would probably be less. Under these conditions the annual cost of keeping cows might be decreased to $60 per year, or near that amount, and the dairyman might be satisfied with a labor return of less than 20 cents per hour.

Conclusion

Though a great many cost figures have been given in the preceding pages, it must be repeated here that the intention has been to exemplify methods of summarizing the cost account, and not to establish a formula for estimating costs. Much criticism may be directed against those who are too ready to get out a pencil and figure out the cost of production. Cost formulas have their usefulness if they are based on comprehensive studies of representative areas, and if their application is restricted to estimation of general conditions within the areas from which they are derived. The dairyman planning the operation of his own farm, however, must depend on records he himself has kept, and it is hoped that the material presented here will be helpful in showing the items of cost that must be recorded, and the manner in which they may best be summarized.

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APPENDIX

LABORATORY EXERCISES

In the teaching of dairy cattle feeding and management, the practicum should form an important part of the work. Usually only one laboratory period is allowed per week, but sometimes there are two. A sufficient number of exercises are outlined in the following pages to occupy two laboratory periods for a full semester. In institutions providing only one laboratory period each week, certain exercises may be omitted without in any way interfering with the continuity of the work. These exercises are marked with a (*). Others may be added if necessary.

In some exercises it may not be possible, with large classes, to schedule all the students to meet at the same time. This applies to such exercises as milking, calf feeding, etc. The class may then be divided into groups and assigned to work at various times outside of regular scheduled periods. With other exercises, such as figuring rations, it is believed desirable that all work be done by the students, independently, in a classroom, under the supervision of an instructor.

In the calculation of rations any one of the various systems may be followed, in accordance with the practice in the particular state in which the instruction is given. In these exercises the Morrison Standard will be used except when otherwise stated.

Feeding

Exercise I. Identification of Feeds.—As many feeds as can be obtained should be placed in convenient containers so that the students can observe and study them. During the laboratory period the names of the different feeds are placed on the containers and the student is required to make a study of the characteristic appearance, odor, weight, bulk, and any other property which the feed may possess. Defects of any particular feeds or characteristics that dis-

tinguish grades or qualities of a particular feed should be discussed. Ready-mixed feeds that are common in the state may also be used. After the students have had time thoroughly to familiarize themselves with the feeds, certain of the feeds should be prepared with labels removed and a test given on identification of feeds.

Reference.—Lecture VI.

Exercise II. Cost of Feeds.—A list of all the common feeds and roughages in common use in the state and the current price per ton should be given to each student. The student should obtain the pounds of digestible protein and total nutrients of each feed from the tables and from these calculate the cost of 100 pounds of feed, of 1 pound of digestible protein and 1 pound of digestible nutrients. This should be kept for calculation of feed costs in the following exercises.

Reference.—Lecture X.

Exercise III.* Requirements for Maintenance and Milk Production.—The requirement for maintenance of cows of varying weights, and for milk production of cows giving various amounts of milk with different fat percentages, by the different standards, should be calculated.

Problems.—1. Calculate the requirements of a 900-pound cow giving 30 pounds of 5 per cent milk daily, by the Wolff-Lehman, Haecker, Morrison, Scandinavian, and Armsby standards.

2. Calculate the requirements of a 1300-pound cow giving 45 pounds of 3.5 per cent milk daily, by the same standards as in Problem 1.

Reference.—Lecture VIII.

Exercise IV.* Calculating Rations.—Rations should be calculated by the more common standards, to familiarize the student with the different standards.

The Scandinavian System

Problems.—1. Calculate a ration for a 1000-pound Jersey cow giving 16.5 pounds of 5.5 per cent milk, when the following feeds are available:

Corn stover	Wheat bran
Clover hay	Cottonseed meal
Corn meal	Gluten feed

2. Calculate a ration for a 1200-pound cow giving 35 pounds of 3.8 per cent milk when the following feeds are available:

Red-clover hay	Corn and cob meal
Corn silage	Ground oats
Buckwheat middlings	Linseed meal

Reference.—Lectures VIII, IX.

Exercise V. Calculating Rations.

Morrison Standard

Problems.—1. Calculate a ration for a 1050-pound cow giving 32 pounds of 4.2 per cent milk when the following feeds are available:

Timothy hay	Wheat bran
Corn silage	Cottonseed meal
Corn meal	Gluten feed

Calculate also the cost of the ration, the feed cost of 100 pounds of milk, and the feed cost per pound of butterfat.

2. Calculate a ration for a 1300-pound cow giving 45 pounds of 4.1 per cent milk with the following feeds available:

Corn silage	Corn and cob meal
Alfalfa hay	Gluten feed
Beet pulp	Hominy
Wheat bran	Ground oats
Cottonseed meal	Linseed meal

Figure the cheapest ration, using only such feeds as are necessary for proper balancing. Figure also the cost of 1 pound of digestible protein and 1 pound of digestible nutrients.

Reference.—Lectures VIII, IX.

Exercise VI. Calculating Rations.

Armsby Standard

Problems.—1. Calculate a ration for an 850-pound cow giving 18 pounds of 4.8 per cent milk with the following feeds available:

Mixed hay	Ground oats
Corn stover	Wheat bran
Corn meal	Linseed meal

Figure the returns for $1 expended for feed when milk sells at $2 per hundred.

2. Calculate a good ration, using any feed on list, for a Guernsey cow weighing 1100 pounds and producing 32 pounds of 4.7 per cent milk.

Consider the characteristics of a good ration. Other things being equal, the cheapest ration is the best. Discuss reasons for using various feeds.

Reference.—Lectures VIII, IX.

Exercise VII.* Calculating Rations for the Herd.—Usually it is not practical to calculate a ration for every cow in the herd and it is therefore necessary to calculate a ration for the entire herd. The student should familiarize himself with the method.

Balance Ration According to Average Cow in the Herd

Problems.—1. Calculate a grain ration for a herd of Jersey cows averaging 20 pounds of 5 per cent milk. The roughage available is corn silage and alfalfa hay. Corn meal and ground oats are available; the other concentrates must be purchased.

2. A man has a herd of 12 Ayrshire cows, averaging 35 pounds of milk per day. He has the following feeds available:

Timothy hay	Corn and cob meal
Corn silage	Ground oats
Corn stover	

Figure the cheapest grain ration to feed, using all of the above feeds and making any additional purchases necessary. Figure the cost of the grain mixture per 100 pounds. Make enough of the mixture to last two weeks. Discuss amount of roughage and grain to feed and reason for purchasing such feeds as are purchased.

Reference.—Lecture X.

Exercise VIII. Calculating Rations for the Herd.—This method is somewhat simpler even than the one shown in Exercise VII. Since there is seldom a deficiency in total nutrients when the herd has all the roughage that they will eat, a roughly balanced ration can be formulated by balancing the protein of the grain mixture to suit the kind of roughage available.

Balancing for Protein

Problems.—1. A dairyman has a herd of 20 Holstein cows averaging 38 pounds of milk per day. He has on hand timothy hay, corn silage, corn and cob meal, and ground oats. Figure a good grain mixture for this herd, using the feeds available and any others necessary. Give reason for the different ingredients, and figure costs. Calculate amount of all feed that will be required in such a herd for a six months' feeding period.

2. A man has a herd of 9 Jersey cows with an average production of 22 pounds. The feeds available are:

Oat straw	Linseed meal
Mangels	Cottonseed meal
Corn and cob meal	Dried beet pulp
Hominy	Wheat bran
Alfalfa hay	Gluten feed

Calculate a good grain mixture, using any of the above feeds. How much feed will be necessary for feeding this herd from September 15 to May 15? Calculate the storage room necessary to store this amount of feed. Give method of feeding, amount fed, and cost of ration.

Reference.—Lecture X.

Exercise IX.* Economy of Heavy Feeding.

Problem.—Assume a 1200- pound Holstein cow with a capacity for producing 50 pounds of 3.5 per cent milk. Will it be economy to feed her enough for only 35 pounds of milk per day? For 25 pounds? Calculate a ration for such a cow by the Morrison Standard for 25, 35, and 50 pounds daily, and include the cost of the ration, the cost of 100 pounds of milk, and of 1 pound of butterfat.

Reference.—Lectures VII, IX.

Exercise X.* Law of Diminishing Returns.—Does it pay to get the greatest production possible from a cow, or is there a point above which it is not profitable to go?

Problem.—Using the feeds and prices as figured in Exercise II, calculate rations for a Jersey cow weighing 900 pounds and with milk testing 5 per cent, under the following conditions, considering pasture worth $2.50 per month:

Production, Pounds Fat	Amount of Pasture	Overhead Expenses Other than Feed
150	Pasture only for 5 months	$50.00
250	Pasture only for 5 months	50.00
350	Pasture and $\frac{1}{3}$ grain ration for 5 months	55.00
450	Pasture and $\frac{1}{4}$ grain ration for 5 months	60.00
550	$\frac{2}{3}$ pasture and $\frac{1}{3}$ roughage, $\frac{3}{4}$ grain ration for 5 months	75.00
650	$\frac{1}{2}$ pasture and $\frac{1}{2}$ roughage, full grain ration for 5 months	85.00
750	$\frac{1}{4}$ pasture and $\frac{3}{4}$ roughage, full grain ration for 5 months	100.00

Find the feed cost per pound of fat; the total cost of 1 pound of fat; the percentage digestible nutrients in roughages; and the percentage digestible nutrients in concentrates. Explain the results by means of graphs.

Reference.—Lecture XIII.

Exercise XI. Calcium and Phosphorus Requirements.

Problem 1.—List the feeds:

High in calcium
Low in calcium
High in phosphorus
Low in phosphorus
High in both calcium and phosphorus
Low in both calcium and phosphorus.

Problem 2.—Figure the mineral needs of a 6-month-old heifer weighing 500 pounds, and see how much alfalfa hay you would need to feed for her to meet her requirements in calcium; in phosphorus. How much if timothy is used instead of alfalfa?

Problem 3.—A 1000-pound cow producing 30 pounds of milk per day is fed 10 pounds of alfalfa hay, 30 pounds of corn silage, 5 pounds of corn, 1 pound of bran, 2 pounds of cottonseed meal. Should she be fed a mineral supplement and how much if bone flour is fed? How much if timothy is used?

How much if she is given 60 pounds of milk with same roughage but 10 pounds of corn, 2 pounds of bran, 4 pounds of cottonseed meal?

ESTIMATED REQUIREMENTS FOR GROWTH

	Grams per 100 lb. Live Weight	
	Phosphorus	*Calcium*
Heifers under 1 year	2.6	4.5
1 to 2 years	1.5	3.0

ESTIMATED REQUIREMENTS FOR MILK PRODUCTION

	Grams Phosphorus	*Grams Calcium*
1000-pound cow maintenance per day	10	18
1-pound milk	0.5 to 0.7	0.9 to 1.1

Reference.—Lecture VII.

Exercise XII.* Mixing Rations.—The students should be given one exercise in the proper mixing of a ration. The feeds should be laid out on the floor in the required amounts and thoroughly mixed.

Reference.—Lecture X.

Exercises XIII, XIV, XV, XVI. Feeding Practice.—Four laboratory periods are devoted to actual feeding practice. One cow or more is assigned to two students, who are required to figure a good ration for this cow, using the feeds available. The students are required to weigh out the feed necessary and to have the cow fed according to their directions. The cow should be weighed at frequent intervals. At the end of a ten-day feeding period, a full report should be submitted.

Reference.—Lectures VI, VII, IX.

Exercise XVII.* Calf Feeding.—One laboratory period should be devoted to calf feeding. A schedule should be arranged in which the students are required to prepare the feeds and to carry out the complete work of feeding calves. This is done under the supervision of the instructor.

Reference.—Lectures XIX, XX.

Exercise XVIII.* Milking by Hand.—The student should demonstrate his ability to milk a cow quickly, completely, and in a satisfactory manner. Those who have had experience in milking before taking the course can demonstrate in one milking whether or not they can do the work satisfactorily. Students without such experience require several milking periods in order to be given credit for this exercise. The work should be done under the supervision of the instructor.

Reference.—Lecture XVIII.

Exercise XIX.* The Use of a Milking Machine.—The students should be given an exercise in the operation of the milking machine. They should be required to assemble the machine, do the milking, and then thoroughly wash and sterilize the machine.

Reference.—Lectures XXVII, XXXI.

Exercise XX.* Valuation of Dairy Animals.—The students should have had a course in dairy-cattle judging before this laboratory exercise. For this, several animals of each class are used, and the student is required to give his estimate of the money value of each of the animals, which should include cows, bulls, heifers, and calves. This exercise should train the student in the purchase of animals and enable him to use his previous training in the deter-

mining of age and to make practical application of his ability to judge production. If the records and the pedigrees of the animals are known, this information should be given. At the end of the period the inventory value of the animal is told to the student.

Reference.—Lectures XXIII, XXIV, XXV, XXVII.

Exercise XXI. Marking and Sketching Cattle.—The students should be familiarized with the different methods of marking cattle and with the method of tattooing and putting tags in the ear.

They should also be furnished with special blanks for registration of animals of the different breeds, and each should be required to make drawings and fill out in full application for registration.

Reference.—Lecture XVIII.

Exercise XXII.* Herd Development.—As many animals as the herd has of one family should be compared with a family that has multiplied but little, thus emphasizing the value of vitality and reproduction. The inheritance of certain characteristics can well be brought out. The daughters of one bull may also be studied, especially in regard to type and production.

Reference.—Lectures XXIV, XXV.

Exercise XXIII.* Demonstrating Mendelian Heredity by the Use of the Heredìscope.—The students should be given heredìscopes and a study made of inheritance in dairy cattle. Problems should be assigned which will illustrate what could be expected in breeding animals of different genetic make-up. Inbreeding, line breeding, and continued use of proved sires should be demonstrated. Two or more students can use one heredìscope. The heredìscopes can be obtained from the American Genetic Association, Washington, D. C., with directions for their use.

Reference.—Lecture XXIII.

Exercise XXIV.* Fitting for Show.—Students are assigned animals to be fitted for show. A careful inspection of the animals is made by the instructor before the fitting begins. Some students are given cows, others bulls, and others heifers or calves. A sufficient supply of the necessary equipment for fitting for show should be on hand and the students should be shown how to use it. It is often desirable at the end of the last period to hold a show so that

lessons in fitting may be pointed out. Also the methods of handling cattle in the show ring can be demonstrated.

Reference.—Lecture XXVIII.

Exercises XXV, XXVI. Barn Plans.—Two exercises in drawing a barn plan are given. Each student is required to hand in drawings according to the following suggestions and specifications. The work can be done either in the classroom or elsewhere. The former is preferable if equipment is available.

Requirements for Dairy Plans

Drawing must be made on regulation-size, white drawing paper (18 by 24 inches). It must be made to a scale of not more than 1 inch equals 6 feet. A margin of ¾ inch must be left on the drawing paper. The drawing must be inked in with regulation black drawing ink. All dimensions of the barn must be shown. A space at the lower right-hand corner of the drawing must be saved for the name, date, scale, and grade. The size of the space should be 4 by 2½ inches. The elevation and floor plan should be shown.

Reference.—Lecture XXX.

Exercise XXVII.* Barn Equipment.—A list of all the equipment in the dairy barn should be made. This should include kind of ties, stalls, feeding arrangement, method of ventilation, and all other equipment. Drawings should be made of such equipment as ventilators, etc. If possible, prices of equipment should be obtained.

Reference.—Lecture XXXI.

Exercises XXVIII, XXIX, XXX, XXXI, XXXII. Dairy-farm Problem.—The object of this dairy-farm problem is to bring together in a fairly comprehensive way some of the factors which must be considered in laying out a dairy-farm business. All points which have a direct and definite bearing upon the dairy problem should be considered. The farm used may be the home farm of the student, some farm with which he is acquainted, now used as a dairy farm, or one that he may be interested in converting into a dairy farm, or the farm may be purely imaginary. The latter, however, is not desirable. The barn plans and equipment in Exercises XXV, XXVI, XXVII may also be made with the same farm in view.

The Dairy-farm Problem

1. *The Layout.*

   A. The farmstead.

   1. Layout of farm, size, etc. To scale, notebook size paper.
   2. Make a list of fields and total expected crop yields.
   3. Location of the house, barn, etc.—to scale.
   4. Estimated value of the dairy barn and equipment.

2. *Give Area, Yield (in Pounds), Use, and Sales of All Crops Grown on the Farm.*—Use a form like the following (following tables are only samples to show character of work and forms to be used):

Crops	Area	Yield per Acre	Total Yield, lb.	Sales, lb.	Used, lb.	Value of Crop

3. *The Livestock.*—Show the numbers and values of animals that you would start with at the beginning of the year, the estimated sales, purchases, and deaths, and the numbers and values at the end of the year, by a table like the following. Indicate the date of sales and of purchases that greatly affect the numbers of animals.

Cows, Heifers, Bulls and Calves

Number, Beginning of Year			Sales			Purchases			Died	Number End of Year		
No.	Value	Total	No.	Value	Total	No.	Value	Total		No.	Value	Total

4. *Feed Used.*—Decide upon the rations to be fed the different animals during the year. Base the rations on good feeding practices and current feed prices. Fill out a table, like the following, to show the feed, pasture, and bedding require-

ments. Include each kind of feed and each kind of roughage separately. If the animals are fed different rations during different parts of the year, give the ration for each period on a separate line.

Number of Animals	Feed Fed During Year								
	Days	Per Day	Total	Per Day	Total	Per Day	Total	Per Day	Total
_______ cows									
_______ heifers 1–2 yrs.									
_______ heifers under 1 yr.									
_______ bulls									
Total for 12 mos.									
Home raised									
Feed used									
Bought feed used									

5. *Cost of Production.*—Considering feeding practice and management on the farm, what would be the probable cost of keeping the dairy herd?

Use the form given below:

Cost:

Feeds—	Grain	$_______
	Hay	_______
	Other dry forage	_______
	Silage	_______
	Other succulence	_______
	Pasture	_______
Labor—	Man _______ hr. _______ per hr.	_______
	Horse _______ hr. _______ per hr.	_______
	Interest on average investment	_______
	Depreciation on dairy cows	_______
	Bedding	_______
	Use of building, 4 per cent value	_______
	Depreciation	_______
	Bull service	_______
	Other costs _______	_______
	_______	_______
	Total	_______

6. *Receipts.*—The receipts from cows should include milk and milk products sold or used on the farm, manure produced, and value of calves at birth; also hides, etc. Use a form like the following:

	Value
Milk sold ______ lb. Price per 100 lb.	$______
Milk used on Farm ______ lb.	______
Manure ______ tons. Price per ton.	______
Calves ______	______
Other receipts ______	______
Butter ______ lb.	______
Cream ______ gal.	______
Total	______

7. *Costs.*—The products of the dairy herd consist of milk, manure, calves, and miscellaneous receipts. In order to find the cost of producing milk, we must assume that manure, calves, and miscellaneous receipts are valued at cost. Subtract the value of manure, calves, and miscellaneous receipts from the total cost to find the cost of producing milk. Use the following form:

Total cost from 5	$______
Value of manure, calves, etc., from 6	______
Cost of producing milk	______
Cost per cwt.	______
Cost per qt.	______
Cost per lb. butterfat	______

8. *Dairy Management Methods* (thesis about 1000–1500 words).
   A. Dairy cows.
      (*a*) Kind and production.
      (*b*) Management, breeding, etc.
      (*c*) Methods of breeding, stabling, etc.
   B. Bulls.
      (*a*) Scheme for stabling, feeding, handling, etc.
   C. Heifers.
      (*a*) Methods of feeding, stabling, etc.
      (*b*) Breeding and management.
   D. Calves.
      (*a*) Scheme for stabling, feeding, handling, etc.
   E. Methods of disposal of dairy animals and products.

9. *Balance Sheet.*—Make a balance sheet showing net returns of whole farm, considering other side lines, expenses, and increase or decrease in total capital.

Reference.—Lectures XXXII, XXXIII, XXXIV, XXXV, and most other lectures.

APPENDIX TABLES

The following tables are taken from several sources and are needed for reference.

TABLE A

Average Dry Matter, Digestible Protein, Total Digestible Nutrients, and Net Energy per 100 Lb. for Ruminants *

	Total Dry Matter, per cent	Digestible Protein, per cent	Total Digestible Nutrients, per cent	Net Energy, therms
Grains and Other Seeds				
Barley, common	90.4	9.3	78.7	79.2
Buckwheat, common	90.4	8.9	64.4	58.4
Cottonseed (whole)	92.7	17.0	91.0	89.5
Cow peas	88.6	19.4	76.5	75.2
Corn, dent, grade No. 1	87.2	7.3	82.5	81.1
Corn, dent, grade No. 2	85.2	7.1	80.6	79.2
Corn, dent, grade No. 3	83.5	7.0	79.0	77.7
Emmer grain (speltz)	91.2	9.6	74.7	67.8
Feterita grain	89.6	10.1	79.7	75.2
Kafir grain	88.6	9.1	80.1	75.2
Milo grain	89.4	8.7	79.9	75.2
Oats, not including Pacific Coast States	91.1	9.4	71.5	71.3
Rye	90.0	10.3	80.1	72.1
Shallu grains	89.8	10.9	81.6	
Soy beans	90.2	32.8	86.2	84.7
Wheat	89.8	11.3	83.6	84.7
Mill By-products				
Alfalfa meal (good)	91.9	10.8	53.9	45.8
Apple pomace, dried	89.4	1.7	60.5	
Apple pomace, wet	21.1	0.5	16.0	
Beet pulp (dried)	92.0	4.8	71.8	70.5
Beet pulp (wet)	11.6	0.8	8.9	9.2
Blood meal or dried blood	91.2	70.7	75.9	74.6
Blood, dried soluble	94.0	85.2	87.5	
Brewers' grains (dried)	92.8	20.7	65.3	62.0
Brewers' grains (wet)	23.9	4.6	16.6	15.8
Buckwheat middlings	88.7	25.8	75.7	
Cocoanut oil meal (o.p.)	90.7	18.7	80.8	72.4
Corn feed meal	89.2	7.6	84.2	
Corn and cob meal	88.5	6.0	75.9	
Corn germ meal	93.0	14.5	79.5	
Corn gluten feed	90.5	22.7	77.4	76.1
Corn gluten meal	91.5	36.5	81.8	80.4
Corn oil meal (o.p.)	91.8	16.7	78.7	70.5
Cottonseed meal, 43% protein grade	93.5	35.0	75.5	74.2

* These data are taken by the special permission of the Morrison Publishing Company from Feeds and Feeding, 20th Ed., by F. B. Morrison.

TABLE A—*Continued*

	Total Dry Matter, per cent	Digestible Protein, per cent	Total Digestible Nutrients, per cent	Net Energy, therms
MILL BY-PRODUCTS—*Continued*				
Cottonseed meal, 41% protein grade	92.8	33.9	73.6	72.3
Cottonseed meal, below 36% protein	92.4	26.6	65.9	64.8
Distillers' corn grains (dried)	93.6	22.3	85.0	83.6
Distillers' rye grains (dried)	94.0	10.1	62.9	53.5
Distillers' grains (wet)	22.4	2.9	17.2	
Fish meal (all analyses)	92.3	47.5	67.6	66.5
Hominy feed	90.9	7.8	85.2	83.8
Linseed meal (o.p.)	91.3	30.6	78.2	76.9
Linseed meal (n.p.)	90.4	31.0	72.3	
Malt sprouts	92.2	20.3	70.6	60.0
Molasses, beet	80.6	2.5	58.8	57.8
Molasses, cane	74.1	0.9	56.6	55.6
Oat meal or rolled oats	91.5	14.7	92.5	
Oat mill feed (usual grade)	93.7	4.0	42.6	39.6
Palmo middlings	94.1	13.3	85.4	
Pea feed	90.4	14.3	78.5	
Peanut oil meal (o.p.)	93.4	38.0	82.1	80.7
Rye middlings	90.2	13.2	77.1	
Soy bean oil meal (all analyses)	91.7	37.7	82.2	80.8
Wheat bran	90.6	13.1	70.2	66.7
Wheat middlings (flour)	89.6	15.0	79.5	75.5
Wheat middlings (standard)	90.0	14.4	78.4	71.4
Wheat Red Dog	89.2	15.2	86.9	85.4
Wheat screenings	90.4	9.7	64.0	52.8
Wheat shorts (brown)	90.1	15.1	76.3	68.7
Wheat shorts (white)	89.7	14.5	86.4	84.9
MILK AND BY-PRODUCTS				
Buttermilk	9.4	3.3	9.1	10.0
Milk, cows	12.8	3.3	16.2	
Skimmilk (centrifugal)	9.6	3.5	8.6	9.5
Skimmilk, dried	93.6	33.1	84.1	92.5
Whey from American cheese	6.6	0.9	6.4	7.0
DRIED ROUGHAGES				
Legume Hays				
Alfalfa hay (all analyses)	90.4	10.6	50.3	41.5
Clover hay, alsike (all analyses)	89.0	7.7	49.0	41.6
Clover hay, crimson	89.4	9.7	48.8	39.0
Clover hay, mammoth red	88.0	6.9	51.7	

TABLE A—*Continued*

	Total Dry Matter, per cent	Digestible Protein, per cent	Total Digestible Nutrients, per cent	Net Energy, therms
Legume Hays—Continued				
Clover hay, red (all analyses)	88.2	7.0	51.9	42.8
Clover hay, sweet (first year)	93.3	14.6	53.5	42.8
Clover hay, sweet (second year)	92.0	10.5	49.9	34.9
Clover and timothy, mixed (all analyses)	88.0	4.4	48.0	38.4
Cow pea hay (all analyses)	90.4	12.6	49.4	40.8
Lespedeza hay (annual)	89.1	9.2	52.2	43.1
Pea hay, field	89.2	11.6	56.9	42.7
Pea and oats hay	89.0	8.9	52.2	39.2
Soy bean hay (all analyses)	90.8	11.1	50.6	38.5
Non-legume Hays				
Barley hay	91.9	4.9	54.1	40.6
Blue grass hay, Kentucky	89.4	4.7	53.3	
Brome grass hay	88.1	5.0	48.9	36.7
Millet hay (common)	90.0	5.2	51.5	36.1
Oat hay	88.0	4.5	46.3	34.7
Orchard grass hay (cut early)	88.6	4.6	49.6	35.2
Red top hay (all analyses)	91.0	4.5	53.6	34.8
Rye hay (all analyses)	91.3	2.8	44.7	
Sudan grass hay (all analyses)	89.2	4.3	48.5	34.0
Timothy hay (all analyses)	88.7	2.9	46.9	35.2
Wheat hay	89.0	3.2	46.5	32.6
STRAWS AND FODDER				
Barley straw	90.0	0.9	44.5	23.6
Buckwheat straw	90.1	1.2	32.3	
Corn fodder, well eared, very dry	91.1	4.1	59.4	38.6
Corn stover, very dry	90.6	2.2	52.2	27.0
Kafir fodder (dry)	91.1	4.6	54.1	35.2
Oats straw	89.6	0.9	44.1	23.3
Rye straw	92.9	0.7	41.2	11.5
Wheat straw	90.1	0.8	35.7	10.0
SILAGES				
Alfalfa, wilted before being ensiled	54.0	5.1	29.0	25.2
Clover, red	24.4	2.0	13.4	11.7
Clover, sweet	28.0	3.5	16.1	
Corn, dent, well matured (all analyses)	28.3	1.3	18.7	14.3
Corn, dent, stover silage	22.6	0.8	13.6	8.8
Cow pea	20.7	1.8	12.2	
Kafir	30.2	1.0	17.3	

TABLE A—*Continued*

	Total Dry Matter, per cent	Digestible Protein, per cent	Total Digestible Nutrients, per cent	Net Energy, therms
SILAGES—*Continued*				
Soy bean	27.2	2.6	15.0	
Sunflower	22.2	1.1	12.6	11.0
Sudan grass	26.1	1.2	15.1	
ROOTS AND TUBERS				
Beets, common	13.0	1.2	10.2	10.2
Beets, sugar	16.4	1.2	13.8	13.8
Carrots	11.9	0.8	9.6	9.6
Mangels	9.4	1.0	7.3	7.3
Potatoes, tubers	21.2	1.1	17.3	17.3
Rutabagas, roots	11.1	1.0	9.3	9.3
Turnips, roots	9.5	1.3	8.5	8.5
GREEN FORAGE				
Alfalfa green (all analyses)	25.4	3.4	14.7	12.8
Barley fodder	22.6	2.3	14.4	12.2
Blue grass, Kentucky	31.8	2.4	18.6	15.4
Brome grass., smooth	33.8	2.9	19.7	15.8
Clover, crimson	17.4	2.3	11.3	
Clover, mammoth red	25.1	2.6	14.9	
Clover, red (all analyses)	25.0	2.6	15.4	13.4
Clover, sweet	22.0	3.0	14.0	11.9
Clover and mixed grasses	27.3	1.9	17.1	14.9
Corn fodder, dent (all analyses)	24.0	1.2	16.3	14.7
Corn stover, green	22.7	0.5	13.0	
Cow peas	16.3	2.3	10.9	9.5
Kafir fodder (all analyses)	23.6	1.3	15.5	14.0
Kale	11.8	1.9	7.8	
Lespedeza, annual	36.6	5.0	20.9	18.2
Millet (foxtail variety)	29.9	1.9	19.1	15.3
Oat fodder	25.4	2.3	15.4	13.1
Peas, field, Canada	16.6	2.9	10.6	9.5
Peas and oats	22.1	2.4	14.1	12.3
Pumpkins, field	10.4	1.3	9.0	
Rye fodder	22.2	2.3	16.2	13.0
Soy beans (all analyses)	24.4	3.2	15.1	13.1
Sudan grass (all analyses)	25.7	1.4	17.7	15.0
Timothy (all analyses)	31.3	1.8	18.1	15.4
Vetch, hairy	18.2	3.5	12.3	
Vetch and oats	26.5	2.9	17.1	
Wheat fodder (all analyses)	26.0	2.6	15.2	12.2

TABLE B *

AMOUNTS OF DIFFERENT FEEDS REQUIRED TO EQUAL ONE FEED UNIT

Feeding Stuff	Feed Required to Equal One Unit	
	Average, lb.	Range, lb.
Concentrates		
Corn, wheat, rye, barley, hominy feed, dried brewers' grains, wheat middlings, oat shorts, peas, Unicorn Dairy Ration, molasses beet pulp	1.0	
Cottonseed meal	0.8	
Oil meal, Ajax Flakes (dried distillers' grains), gluten feed, soy beans	0.9	
Wheat bran, oats, dried beet pulp, barley feed, malt sprouts, International Sugar Feed, Quaker or Sugarota molasses or Dairy Feed, Sucrene Dairy Feed, Badger, Dairy Feed, Schumacher Stock Feed, molasses grains	1.1	
Alfalfa meal, Victor feed, June Pasture, alfalfa molasses feeds	1.2	
Hay and Straw		
Alfalfa hay, clover hay	2.0	1.5– 3.0
Mixed hay, oat hay, oat and pea hay, barley and pea hay, red-top hay	2.5	2.0– 3.0
Timothy hay, prairie hay, sorghum hay	3.0	2.5– 3.5
Corn stover, stalks or fodder, marsh hay, cut straw	4.0	3.5– 6.0
Soiling Crops, Silage, and Other Succulent Feeds		
Green alfalfa	7.0	6.0– 8.0
Green corn, sorghum, clover, peas and oats, cannery refuse	8.0	7.0–10.0
Alfalfa silage	5.0	
Corn silage, pea-vine silage	6.0	5.0– 7.0
Wet brewers' grains	4.0	
Potatoes, skimmilk, buttermilk	6.0	
Sugar beets	7.0	
Carrots	8.0	
Rutabagas	9.0	8.0–10.0
Field beets, green rape	10.0	
Sugar-beet leaves and tops, whey	12.0	
Turnips, mangels, fresh beet pulp	12.5	10.0–15.0

The value of pasture is generally placed at 8 to 10 units per day, on the average, varying with kind and condition.

* From Wis. Exp. Sta. Circ. of Information 37.

TABLE C *

AVERAGE WEIGHTS OF DIFFERENT FEEDING STUFFS

Feeding Stuff	One Quart Weighs	One Pound Measures
Barley meal	1.1 lb.	0.9 qt.
Barley, whole	1.5 "	0.7 "
Brewers' dried grains	0.6 "	1.7 "
Corn and cob meal	1.4 "	0.7 "
Corn bran	0.5 "	2.0 "
Corn meal	1.5 "	0.7 "
Corn, whole	1.7 "	0.6 "
Cottonseed meal	1.5 "	0.7 "
Distillers' grains, dried	0.5–0.7	1.0–1.4
Germ oil meal	1.4 lb.	0.7 qt.
Gluten feed	1.3 "	0.8 "
Gluten meal	1.7 "	0.6 "
Hominy meal	1.1 "	0.9 "
Linseed meal, (n. p.)	0.9 "	1.1 "
Linseed meal, (o. p.)	1.1 "	0.9 "
Malt sprouts	0.6 "	1.7 "
Oats, ground	0.7 "	1.4 "
Oats, whole	1.0 "	1.0 "
Rye meal	1.5 "	0.7 "
Rye, whole	1.7 "	0.6 "
Wheat bran	0.5 "	2.0 "
Wheat, ground	1.7 "	0.6 "
Wheat middlings, flour	1.2 "	0.8 "
Wheat middlings, standard	0.8 "	1.3 "
Wheat, whole	1.9 "	0.5 "

Note: 2150.42 cubic inches equal one bushel; 67.2 cubic inches equal one quart dry measure.

* Farmers' Bul. 222.

TABLE D *

MINERAL ELEMENTS OF FEEDING STUFFS—PARTS PER 100 OF FRESH SUBSTANCE

Feeds	Ash	Calcium	Phosphorus	Magnesium	Potassium	Sodium	Sulphur	Chlorine
Wheat	1.64	0.050	0.373	0.130	0.520	0.031	0.198	0.084
Wheat bran	6.06	0.125	1.110	0.531	1.320	0.201	.267	.090
Wheat middlings	4.12	0.096	0.876	0.383	1.021	0.165	.234	.025
Red dog flour	3.72	0.120	0.830	0.290	0.380	0.660	.260	.140
Corn	1.21	0.012	0.260	0.108	0.340	0.026	.147	.063
Corn bran	1.18	0.027	0.139	0.078	0.365	0.000	.110	.046
Pearl hominy	0.53	0.004	0.098	0.032	0.135	0.000	.160	.046
Gluten feed	3.18	0.247	0.542	0.220	0.250	0.424	.585	.090
Distillers' grains (corn)	1.38	0.043	0.290	0.050	0.013	0.142	.470	.060
Distillers' grains (rye)	3.39	0.130	0.420	0.179	0.041	0.071	.374	.026
Malt sprouts	5.70	0.147	0.690	0.180	0.203	1.350	.800	.360
Oats	3.38	0.102	0.395	0.118	0.419	0.168	.195	.070
Kafir corn	1.18	0.012	0.239	0.125	0.254	0.058	.164	.014
Rice	0.28	0.008	0.093	0.025	0.036	0.029	.102	.036
Soy beans	5.06	0.210	0.592	0.223	1.913	0.343	.406	.024
Cow peas	3.69	0.100	0.456	0.208	1.403	0.162	.240	.040
Linseed meal	5.80	0.362	0.705	0.488	1.098	0.253	.408	.058
Cottonseed meal	6.98	0.266	1.352	0.548	1.656	0.259	.490	.038
Beet pulp	2.91	0.660	0.062	0.256	0.314	0.167	.125	.043
Mangel wurzel	1.18	0.015	0.030	0.041	0.444	0.082	.026	.158
Clover hay	6.76	1.142	0.169	0.270	1.701	0.062	.176	.239
Alfalfa hay	6.38	1.046	0.221	0.370	0.770	0.453	.276	.149
Soy-bean hay	7.67	1.232	0.212	0.619	1.586	0.130	.231	.075
Cow-pea hay	10.76	1.814	0.253	0.980	0.780	0.646	.315	.149
Timothy hay	3.20	0.177	0.113	0.102	0.564	0.317	.149	.183
Millet hay	5.60	0.310	0.165	0.249	1.273	0.094	.151	.117
Corn stover	6.52	0.472	0.095	0.086	1.718	0.061	.174	.287
Blue-grass hay	4.82	0.308	0.222	0.220	1.290	0.129	.307	.215
Wheat straw	3.45	0.205	0.036	0.060	0.796	0.224	.150	.198
Corn silage †	1.74	0.084	0.069	0.062	0.031	0.009	.020	.041
Skimmilk	0.69	0.128	0.094	0.014	0.122	0.047	.034	.091
Whey	0.56	0.044	0.039	0.008	0.167	0.028	.008	.118
Bone flour	......	23.900	14.940	1.160	0.065	0.091		

* Ohio Exp. Sta. Bul. 255. † W. Va. Exp. Sta.

TABLE E *

ESTIMATED WEIGHT OF SETTLED SILAGE †

Depth of Silage, foot	Estimated Weight of Silage to the Cubic Foot at This Depth	Average Weight of Silage to the Cubic Foot to This Depth	10 Ft. Diameter	12 Ft. Diameter	14 Ft. Diameter	16 Ft. Diameter	18 Ft. Diameter	20 Ft. Diameter
	Lb.	Lb.	Tons	Tons	Tons	Tons	Tons	Tons
1	32.0	32.0	1.26	1.81	2.46	3.22	4.07	5.03
2	32.7	32.4	2.54	3.66	4.98	6.51	8.23	10.17
3	33.4	32.7	3.85	5.54	7.55	9.86	12.46	15.40
4	34.1	33.1	5.19	7.48	10.19	13.31	16.81	20.79
5	34.8	33.4	6.55	9.45	12.85	16.78	21.21	26.22
6	35.4	33.7	7.94	11.44	15.56	20.32	25.68	31.75
7	36.0	34.1	9.37	13.50	18.37	23.99	30.31	37.48
8	36.6	34.4	10.80	15.56	21.19	27.66	34.95	43.21
9	37.4	34.7	12.26	17.66	24.04	31.39	39.66	49.03
10	38.0	35.0	13.74	19.79	26.95	35.18	44.45	54.95
11	38.4	35.3	15.25	21.95	29.85	39.02	49.31	60.96
12	38.8	35.6	16.77	24.15	32.89	42.93	54.25	67.07
13	39.2	35.9	18.32	26.38	35.93	46.90	59.27	73.27
14	39.6	36.2	19.90	28.65	39.02	50.93	64.34	79.57
15	40.0	36.4	21.44	30.88	42.04	54.87	69.34	85.72
16	40.2	36.7	23.05	33.21	45.21	59.02	74.57	92.19
17	40.4	36.9	24.63	35.47	48.30	63.04	79.67	98.49
18	40.6	37.1	26.22	37.76	51.42	67.11	84.81	104.84
19	40.8	37.3	27.83	40.07	54.56	71.22	90.00	111.27
20	41.0	37.5	29.45	42.41	57.75	75.38	95.27	117.75
21	41.2	37.6	31.00	44.65	60.79	79.35	100.28	123.97
22	41.4	37.8	32.65	47.02	64.03	83.58	105.61	133.56
23	41.6	38.0	34.32	49.41	67.29	87.84	110.50	137.22
24	41.8	38.1	35.90	51.70	70.40	91.90	116.13	143.56
25	42.0	38.3	37.60	54.15	73.72	96.23	121.60	150.33
26	42.2	38.4	39.20	56.46	76.87	100.34	126.80	156.75
27	42.4	38.6	40.92	58.94	80.24	104.74	132.36	163.63
28	42.6	38.7	42.55	61.28	83.43	108.90	137.62	170.13
29	42.8	38.9	44.30	63.79	86.86	113.37	142.27	177.11
30	43.0	39.0	45.94	66.08	90.09	117.69	148.59	183.69

* Mo. Agr. Exp. Sta. 154.

† When extreme conditions of any kind prevail it is wise to make some allowances, and the following are suggested:

1. When the corn is put in the silo in a less mature condition than usual, for example, in the milk stage, or at the beginning of the dough stage, add 10 to 15 per cent to the weight given in the table.
2. If the grain is unusually heavy in proportion to the stalk, add 5 to 10 per cent to the figures as found by the table.
3. If the corn is considerably past the usual stage of maturity and clearly contains less water than usual, deduct 10 to 15 per cent.
4. If very little or no grain is present, deduct 10 per cent.

TABLE F

Gestation Table for Dairy Cows

Date of Service	Due to Calve	Date of Service	Due to Calve	Date of Service	Due to Calve	Date of Service	Due to Calve	Date of Service	Due to Calve	Date of Service	Due to Calve	Date of Service	Due to Calve	Date of Service	Due to Calve	Date of Service	Due to Calve	Date of Service	Due to Calve	Date of Service	Due to Calve	Date of Service	Due to Calve
Jan.	Oct.	Feb.	Nov.	Mar.	Dec.	Apr.	Jan.	May	Feb.	June	Mar.	July	Apr.	Aug.	May	Sept.	June	Oct.	July	Nov.	Aug.	Dec.	Sept.
1	10	1	10	1	8	1	8	1	7	1	10	1	9	1	10	1	10	1	10	1	10	1	9
2	11	2	11	2	9	2	9	2	8	2	11	2	10	2	11	2	11	2	11	2	11	2	10
3	12	3	12	3	10	3	10	3	9	3	12	3	11	3	12	3	12	3	12	3	12	3	11
4	13	4	13	4	11	4	11	4	10	4	13	4	12	4	13	4	13	4	13	4	13	4	12
5	14	5	14	5	12	5	12	5	11	5	14	5	13	5	14	5	14	5	14	5	14	5	13
6	15	6	15	6	13	6	13	6	12	6	15	6	14	6	15	6	15	6	15	6	15	6	14
7	16	7	16	7	14	7	14	7	13	7	16	7	15	7	16	7	16	7	16	7	16	7	15
8	17	8	17	8	15	8	15	8	14	8	17	8	16	8	17	8	17	8	17	8	17	8	16
9	18	9	18	9	16	9	16	9	15	9	18	9	17	9	18	9	18	9	18	9	18	9	17
10	19	10	19	10	17	10	17	10	16	10	19	10	18	10	19	10	19	10	19	10	19	10	18
11	20	11	20	11	18	11	18	11	17	11	20	11	19	11	20	11	20	11	20	11	20	11	19
12	21	12	21	12	19	12	19	12	18	12	21	12	20	12	21	12	21	12	21	12	21	12	20
13	22	13	22	13	20	13	20	13	19	13	22	13	21	13	22	13	22	13	22	13	22	13	21
14	23	14	23	14	21	14	21	14	20	14	23	14	22	14	23	14	23	14	23	14	23	14	22
15	24	15	24	15	22	15	22	15	21	15	24	15	23	15	24	15	24	15	24	15	24	15	23
16	25	16	25	16	23	16	23	16	22	16	25	16	24	16	25	16	25	16	25	16	25	16	24
17	26	17	26	17	24	17	24	17	23	17	26	17	25	17	26	17	26	17	26	17	26	17	25
18	27	18	27	18	25	18	25	18	24	18	27	18	26	18	27	18	27	18	27	18	27	18	26
19	28	19	28	19	26	19	26	19	25	19	28	19	27	19	28	19	28	19	28	19	28	19	27
20	29	20	29	20	27	20	27	20	26	20	29	20	28	20	29	20	29	20	29	20	29	20	28
21	30	21	30	21	28	21	28	21	27	21	30	21	29	21	30	21	30	21	30	21	30	21	29
22	31	......	Dec.	22	29	22	29	22	28	22	31	22	30	22	31	......	July	22	31	22	31	22	30
......	Nov.	22	1	23	30	23	30	......	Mar.	......	Apr.	......	May	......	June	22	1	......	Aug.	......	Sept.	......	Oct.
23	1	23	2	24	31	24	31	23	1	23	1	23	1	23	1	23	2	23	1	23	1	23	1
24	2	24	3	......	Jan.	......	Feb.	24	2	24	2	24	2	24	2	24	3	24	2	24	2	24	2
25	3	25	4	25	1	25	1	25	3	25	3	25	3	25	3	25	4	25	3	25	3	25	3
26	4	26	5	26	2	26	2	26	4	26	4	26	4	26	4	26	5	26	4	26	4	26	4
27	5	27	6	27	3	27	3	27	5	27	5	27	5	27	5	27	6	27	5	27	5	27	5
28	6	28	7	28	4	28	4	28	6	28	6	28	6	28	6	28	7	28	6	28	6	28	6
29	7	29	8	29	5	29	5	29	7	29	7	29	7	29	7	29	8	29	7	29	7	29	7
30	8	......	......	30	6	30	6	30	8	30	8	30	8	30	8	30	9	30	8	30	8	30	8
31	9	......	......	31	7	......	......	31	9	......	......	31	9	31	9	......	......	31	9	......	......	31	9

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